Functional Implications of MALNUTRITION

MEXICO PROJECT

Final Report

Human Nutrition
Collaborative Research
Support Program

People Cannot Live by *Tortillas* Alone:

The Results of the Mexico Nutrition CRSP

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We are most grateful to the families of the Solís valley who tolerated the invasion of their lives by the CRSP project investigators. Many hundreds of field workers receive our thanks for obtaining information of excellent quality, even though this required walking many kilometers, often in bad weather, and asking the same questions again and again. The *Jefes de Area* deserve special mention as they were responsible for day-to-day organization and quality control. Our efforts were well-supported by hard-working, competent administrative and data management staff both in Mexico and in Connecticut. The investigators recognize the unique dedication of Dr. Doris Calloway who contributed greatly to getting the Nutrition CRSP funded in the first place, and who coordinated the research design and conduct such that the highest scientific standards were attained. Within the Office of Nutrition of the Agency for International Development, the late Dr. Martin Forman had the foresight to recognize the need for this research, and his successor Dr. Norge Jerome supported the funding of the last two years of data analysis which made this report possible. Finally, all of us thank our families, friends and colleagues for supporting us through the last ten years, when so much of our lives has been dedicated to this research. Because the results clearly indicate that feasible changes in present nutrition policies can have a major impact on the quality of life of marginally malnourished people, we believe that all of these efforts were worth-while. Our plea is that the appropriate agencies will take the responsibility for moving to the next step, which is the testing and implementation of the interventions indicated by the results of the Nutrition CRSP. Unless they do, the lives of billions of people will continue to be needlessly handicapped by the pervasive effects of marginal malnutrition which are clearly documented in this report.

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Chapter One.
Introduction

The History of the Nutrition CRSP.

The Nutrition CRSP (Collaborative Research Support Program) was designed to test whether chronic mild-to-moderate malnutrition affects functional outcomes of individuals. This research topic had emerged as the highest priority of Study Team IX (Nutrition) at the 1977 World Food and Nutrition Study of the US National Academy of Nutritional Sciences [1]. At that time opinion was changing concerning the existing concept that inadequate quantity and/or quality of protein was the major cause of undernutrition in individuals in developing countries. Rather, it was now believed, chronic food shortage and subsequent energy deficiency was likely to be the most common problem. However, because chronic energy deficiency should lead to a continuous loss of body weight - a phenomenon not actually observed in the majority of individuals in developing countries - it was thought there might be physiological adaptations (such as reduced BMR or lower energy expenditure in physical activity) to energy deficit that enable individuals to function perfectly well on a lower energy intake. On the other hand, it was equally plausible that a number of important human functions would be adversely affected by marginal malnutrition. The most likely of these were hypothesized to be growth, psychological development, immune function (morbidity), reproductive competence and social competence. For these reasons, the general approach was to explore relationships between an individual's intake of energy (and other nutrients and foods) and their performance in these functions.

In 1981 the US Agency for International Development (US AID) funded the Nutrition CRSP in Egypt, Kenya and Mexico, with financial and technical oversight from the University of California, Berkeley. The different countries were selected in order to make the study findings more generalizable, but the main investigators worked closely together to ensure that the research questions and methods were as similar as possible across country projects. This report describes the research in Mexico. Further details of the field work, and initial results, have been published previously [2,3].

The Mexico Nutrition CRSP.

The Mexico CRSP started in early 1982 when the Principal Investigators (Drs. Lindsay H. Allen and Gretel H. Pelto from the University of Connecticut, and Dr. Adolfo Chávez from the Instituto Nacionál de la Nutrición Salvador Zubirán (INNSZ) started to select possible research sites and personnel. The field site chosen was the Solís Valley, described in detail in Chapter

Two. The main participants in the Mexico CRSP are named in Table 1.1. Dr. Alfonso Mata was the Field Director, and Dr. Homero Martinez the Solís clinic Director, for most of the data collection phase. The research was almost entirely conducted by the Mexican team, with frequent field visits by the US Principal Investigators who were in residence during most of the first two years. In addition, a few graduate students from Connecticut formed part of the research team in Solís, and a substantial administrative and data management group was maintained at Connecticut.

The data collection phase started with a pilot study in a nearby community in 1982, followed by a year of further personnel recruitment and training, instrument development and testing, purchasing equipment and supplies, and building community relations. The data analyzed in this report were collected between January, 1984 and May, 1986. The time between the end of data collection and the first Final Report [3] was spent in data cleaning and analysis, at both INNSZ and Connecticut. Funding for additional data analysis became available in early 1990, for a 2-year period, and most of the analyses presented in this report were performed during that time. At Connecticut the data analysis team consisted of Drs. Allen, Pelto and Backstrand, supported by C. Capacchione and graduate students. In Mexico the analyses were supervised by Drs. Chávez and Martinez with the assistance of Luciano Dominguez and Drs. Enrique Rios and Francisco Aranda.

Structure of This Report.

The report begins with a description of the Solís valley, followed by the research design and methods. Chapter Five illustrates the early growth failure of children, providing the background for subsequent comments and analyses. Chapters Four, and Six to Eight focus on the food system, dietary adequacy and quality, social predictors of dietary quality, and anemia and nutrient deficiencies that result from poor dietary quality. After describing the morbidity/sanitation situation we move to a "life span" approach, using bivariate and multivariate analyses of factors predicting the growth, cognitive performance and behavior of the Solís infants and children. Most chapters end with a summary and, where appropriate, a list of suggested policy implications. The report ends with a summary of the results, and their policy implications from a nutritional perspective.

We chose to write this report as if it would to be read by those responsible for making policies directed at nutrition-related issues, as well as by those interested in the scientific aspects of the research. For this reason we have sometimes omitted more complex analyses and discussions which are available in published articles. A list of these articles is included as Appendix One.

Table 1.1: Participants in the Mexico CRSP.

University of Connecticut

Dr. Lindsay Allen	Principal Investigator
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Dr. Pertti J. Pelto	Co-Investigator, Social Data
Dr. Jeffrey Backstrand	Data Manager and Analyst
Denise Beaudoin	Secretary
Dr. Bruce Bernstein	Project Administrator, 1987 Final Report Editor
Dr. Anne Black	Graduate Student, Laboratory Analyses
Robert Braden	Data Management Assistant
Connie Capacchione	Data Management Assistant
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Instituto Nacionál de la Nutrición Salvador Zubirán

Dr. Adolfo Chavez	Principal Investigator
Dr. Alfonso Mata	Physician, Field Director
Dr. Homero Martinez	Physician, Clinic Director, Data Analysis

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Dr. Julia Beatriz C.	RMR, Activity, Anthropometry
Gloria Contreras	Anthropometry
Ramon Lira	Data Management
Dr. Gerardo Lezama	Clinic Head
Eulalia Martinez	Psychology
Margarita de Mata	Laboratory
Luz Maria Meneses	Census, Social Data, Productivity
Dr. Enrique Rios	Data Analysis
Elsa Molina Rivera	Food Intake, Coordinator of Area Chiefs

Area Chiefs (cont)

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Dr. Tiffany Field	Infant and Child Psychology
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Chapter Two.
The Community Context

The Six Research Communities

The Mexico Nutrition CRSP research was conducted during 1982-1986 in six small, neighboring communities located in the rural Solís Valley of central Mexico (see Map 2.1). These communities ranged in population from 700 to 1,500 individuals (members of 100 to 214 households). Subsistence in these communities is usually some combination of small-scale maize agriculture, local wage labor, and male migration to Mexico City (approximately 150 kilometers distant). On occasion, migrants travel as far as the U.S. and Canada. In many respects, the six communities are representative of the thousands of small, *mestizo* (Mexican-oriented, Spanish-speaking) agricultural villages found throughout the rural, central highlands of Mexico.

The Physical Environment

The Solís Valley is a long, narrow valley created by the passage of the Lerma River. The valley is 4 to 10 miles in breadth and approximately 40 miles in length. The Nutrition CRSP research occurred at the southern end of the valley, within the *municipio* (township) of Temascalcingo, and the State of Mexico (see Map 2.2).

A highland environment, the altitude of the valley floor is approximately 2,400 meters (7,900 feet), while the surrounding mountains reach as high as 3,250 meters (10,700 feet). The high altitude moderates the effects of the southern latitude. A rainy season occurs during late May through mid-September, when most of the annual rainfall occurs. During the remainder of the year, the climate is dry. This dry season is further divided by significant risk of frost from late October through March.

Land, Maize, and Tortillas

Prior to the Mexican Revolution, before 1931, most Solís Valley lands were owned by a few powerful *haciendas*. The moderate climate, fertile lands, and peasant labor made the valley an important producer of wheat, barley, and cattle [1]. In the wake of the Revolution came land reform and the destruction of the hacienda system. The wealthy *hacienda* Solís, once sixth richest in Mexico, was broken up and its lands dispersed among the peasants [2,3]. At this time, the six CRSP communities received *hacienda* lands as *ejido* (communal lands protected from private ownership by the Mexican constitution). Peasant families received small allotments of *ejido* land for their private use. Most of these were then devoted to small-scale, family-based agriculture.

The establishment of the *ejido* system transformed the agriculture of the valley. Most valley land was used for maize production, and the valley became a patchwork of small, household-controlled cornfields. The small land holdings (averaging 1 or 2 hectares) produce relatively small quantities of maize, mostly grown to make the *tortillas* that are eaten on a daily basis by the household members. Relatively little home-produced maize is sold.

Because *tortillas* provide most individuals with more than 50% of their daily energy needs, the local diet is closely tied to subsistence agriculture. However, most other foods in the diet are now purchased. Major exceptions for some households are eggs, milk, chicken, *nopales* (cactus leaves), and *quelites* (a wild green), foods that are home produced or gathered to some extent. However, most households purchase food that provides at least 30% of their energy need. These foods are usually purchased at small local stores (*tiendas*), where selection is limited, or at larger open-air markets in Solís and Temascalcingo. Many, if not most, of these foods have their origin outside of the Solís Valley. Therefore, the Solís Valley diet, although based on a locally produced commodity, has become increasingly delocalized as incomes increase, populations grow, and the commercial food system expands and diversifies.

The Development of the Solís Valley

In past decades, the Mexican government has expended considerable effort on development projects aimed at improving agricultural production in the Solís Valley. Much of this effort has been aimed at reversing the small-scale maize agriculture that developed in the wake of the Revolution. In the 1940s loans were offered for the establishment of *ejido*-based farms, and efforts were made to establish a sheep-farming industry. In the 1950s, attempts were made to improve valley wheat production by introducing chemical fertilizer and hybrid varieties of wheat. An agricultural extension, technical assistance program was created for local farmers. In the 1960s, efforts were made to introduce farmers to new agricultural crops (such as cold climate fruits and large-scale dairying). In the 1970s, Green Revolution strains of maize were introduced and the cooperative plowing of *ejidal* lands was encouraged as was large-scale cooperative dairy farming. Few of these efforts appear to have had any major effect on local patterns of small-scale, subsistence-based maize farming.

One important change since the Revolution has been the establishment of a network of schools for the provision of free public education. Most adults in the six communities have been exposed to some schooling. The median duration of education for persons in their early forties is one year, while persons 18-24 years have appreciably more education (a median of 4 years for females, and 6 years for males). As a result of local schools, most adults report being able to read and write (59% of women, and 76% of men). As would be expected, levels of literacy are highest among the youngest adults.

The infrastructure of the valley has been improved considerably in recent decades. Two-lane paved roads connect the valley with important towns, and these are traveled by the buses that connect the Solís Valley with the rest of Mexico. Within the valley, local buses and taxis provide public transportation between villages and Temascalcingo. While a few individuals own automobiles, most shorter trips are made by walking or on horse or burro.

Other improvements in the Solís Valley have occurred in the areas of electrification, flood control, and water supply. In 1980, 64% of the *municipio*'s 7,499 dwellings were reported as having electricity. Most of this occurred during the previous 20 years. Among the many effects of electrification has been the exposure of valley households to the Mexican electronic media. Over half of CRSP households (54%) reported owning a radio, while 40% owned a television. The sociocultural results of this revolution in communication are incalculable.

Flood control was another major public works project in the valley. Until the 1950s, the Lerma River regularly overflowed its banks, depositing the silt that made the soil so fertile, but flooding maize crops in the process. During the 1960s a major flood control project was undertaken, and the Lerma now flows the length of the valley between dikes. At the same time, irrigation canals were constructed to improve water distribution within the valley (2).

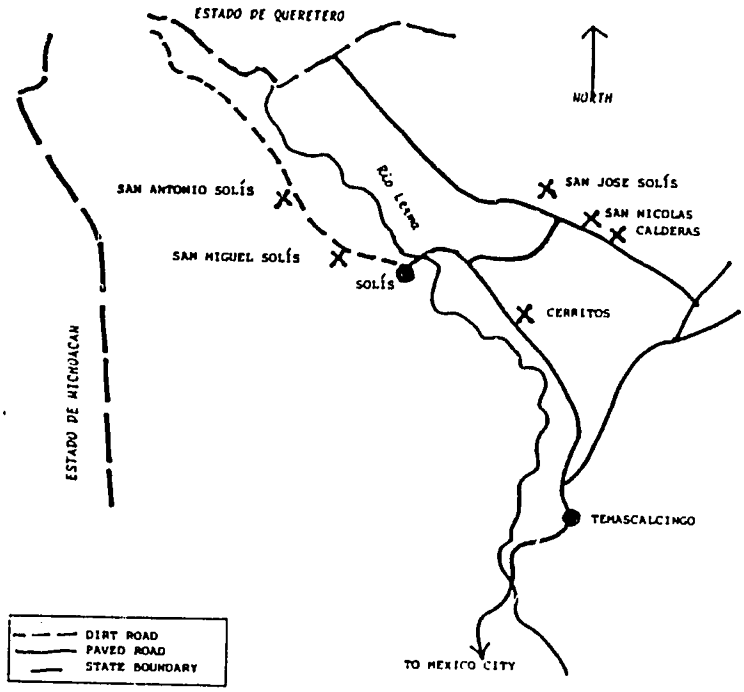
Efforts have also been made to improve the water supply for the human population. In the 1930s an aqueduct was built to provide Temascalcingo with water. In later years piped water has been provided to many villages. However, many if not all of these water supplies are contaminated by fecal matter and parasites.

High Fertility, Population Growth, and Migration

Despite the many social, cultural, and economic changes in the valley during the past decades, human fertility remains high in the Solís Valley. In the six CRSP communities, women typically give birth to 8-12 children by the age of 45 [4]. The median birth interval for adult women is approximately 27 months. As a result, families are large, and the population dominated by children. The age-sex pyramid for the six communities is broad-based, as is common in the Third World (see Figure 2.1), and half of the population is under the age of 16 years.

High fertility and relatively low mortality have resulted in steady population growth (see Figure 2.2). The 1930 Mexican census gave the population of the *municipio* of Temascalcingo as 16,000. By 1980 the population had increased to 46,000. From 1970 to 1980, the population increased by 37%. Although the town of Temascalcingo has grown (in 1980 the population was approximately 7,000), most of the *municipio*'s population growth has occurred in rural communities such as those in the CRSP.

Map 2.1: Map of the Location of the Solís Valley in Mexico.



Map 2.2: Map of the Locations of the Research Communities in the Solís Valley.

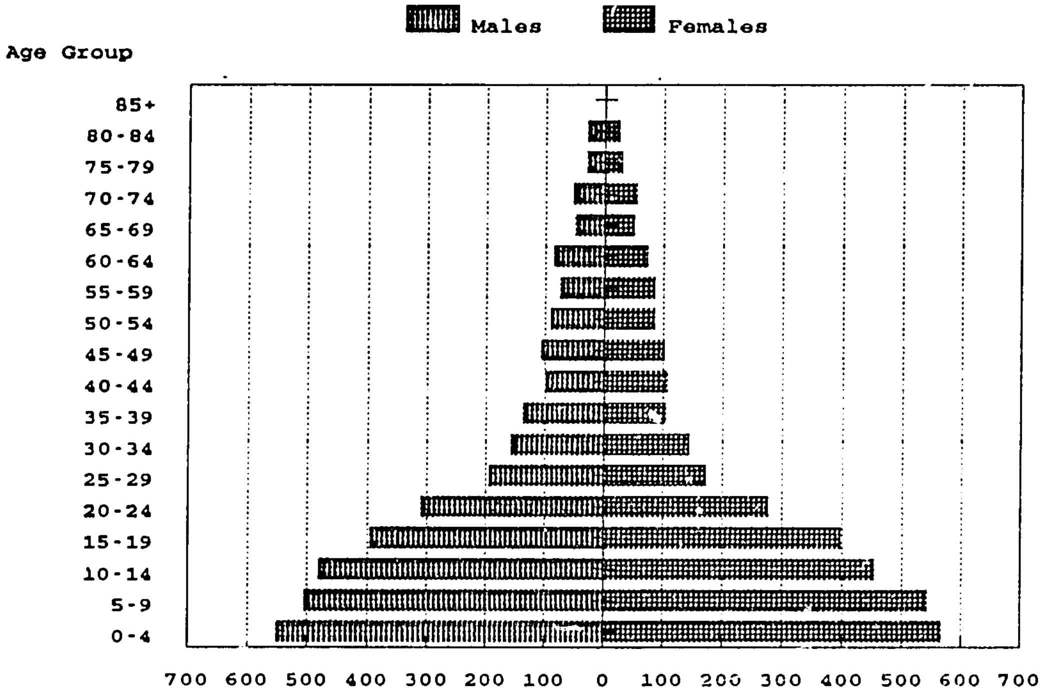


Figure 2.1: Age-sex pyramid for six target communities showing the number of persons of each sex in five year age groups.

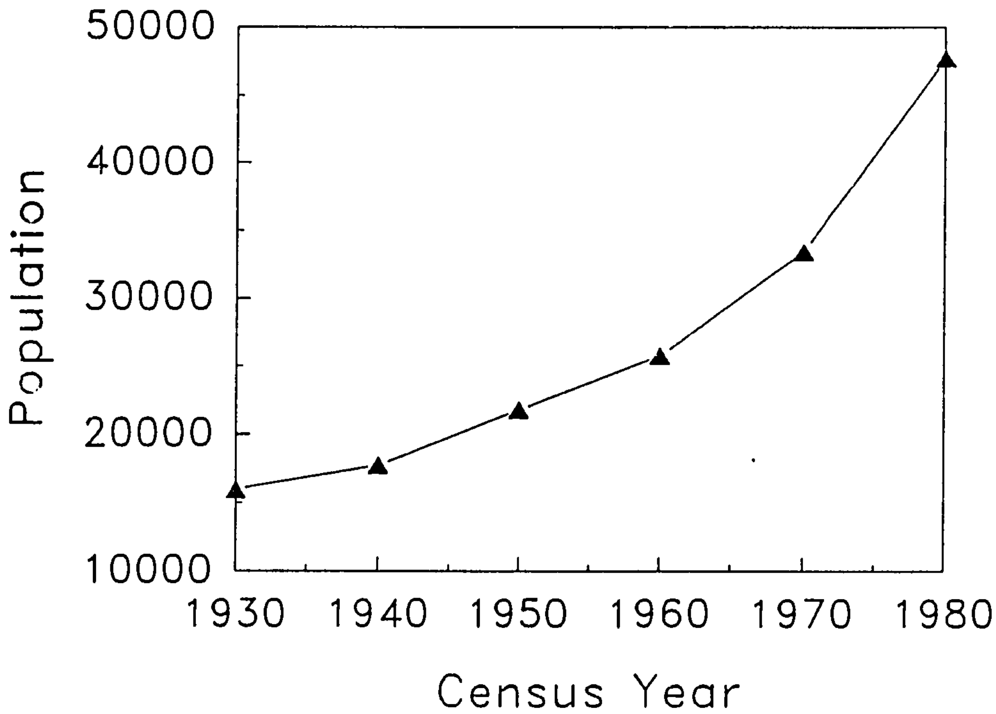


Figure 2.2: Growth in population of the municipio of Temascalcingo, 1930-1980.

Rapid population growth, limited economic opportunities, improved transportation to and from Mexico City, and a variety of other factors have resulted in high rates of migration from the valley since at least 1950. Most of this migration occurs for those in their late teens and early twenties. Analyses based on *municipio* census data suggest that at least 30% of persons permanently migrate from the valley at this time. In addition, some men live in Mexico City (or elsewhere) while supporting a family in the valley. Many of these commute back to the valley on the weekends. Other men migrate during the summer when farm opportunities are greatest.

The Environment of Health and Disease

The rural Solís Valley environment is one that is likely to foster disease. Household members usually urinate and defecate in the surrounding fields. Domestic animals are commonly kept in the yard or near the house. During the rainy season, run-off combines with soil and the accompanying fecal matter to form streams and puddles that must be forded, while insect- and wind-borne contamination is highest during the dry season. Local water supplies are rarely free of contamination, despite the presence of standpipes, and water treatment is rare. As a result, parasitic infestations are endemic. In addition, refrigeration is uncommon and hygiene practices of many households and vendors are less than optimal.

Housing conditions are crowded. Few households have more than three rooms and families are large. Most houses are constructed of tile roofs and earth walls, and many households (40%) have at least one dirt floor. Few houses are heated, except for a wood fire used for cooking in some cases.

Health care in the valley is provided by a mixture of the public and private sector, and formal and informal medicine. In the town of Solís, the CRSP headquarters, is the *Unidad Medico Social* which, during the study period, had X-ray and laboratory facilities, a small number of beds for patients, a delivery room, two consultant physicians, a medical director, and library. Medical services were available to the local residents. In addition, the town of Temascalcingo has other publicly supported clinics, several private physicians, and five pharmacies. The latter commonly provide medical advice in addition to selling medications (with or without prescriptions). Local merchants may also sell patent medicines and 'over-the-counter' drugs. Lastly, practitioners of traditional medicine remain an option in the valley, but do not appear to be widely patronized.

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Chapter Three.
Study Design and Methods

The Goal of the Nutrition CRSP

The Nutrition CRSP was an investigation of the relationship between food intake and several functional measures important in human life, including physical growth and psychological development, activity, morbidity, and pregnancy outcome. The research was designed to provide a strong basis for understanding the relationship of diet to several human functions. A longitudinal design was adopted in an attempt to strengthen any argument of causation. The research was conducted in three very different populations (the rural Solís Valley of Mexico, the peri-urban community of Kalama in Egypt, and the rural area of Embu in Kenya) to enhance the generalizability of the results. The data were collected on different categories of target individuals (pregnant mothers and their infants, fathers, preschoolers, and school-aged children) to demonstrate the potentially broad social effects of inadequate food intake. Several different types of measures (e.g., psychology, growth, and morbidity) were collected on each type of individual to identify the range of dietary effects on a single individual, and interrelationships among those effects. The three Nutrition CRSP projects employed parallel research designs, the cornerstone of which was the collection of extensive, longitudinal information on individual and household level food intakes. These dietary measures comprise the most extensive set of food intake data collected in the less developed world, permitting the most valid and reliable measures of food intake yet possible on Third World populations. In addition to the dietary data, other information was collected longitudinally, including anthropometry, morbidity, and psychology. A variety of other data was collected at selected points in time, including information on activity, behavior, sanitation, and socioeconomic aspects of the household.

The Mexico CRSP Research Sample

All three Nutrition CRSP projects selected their subjects according to the same criteria. The samples were opportunistic rather than random. In Mexico, the sample represents a nearly complete representation of all the eligible households in the six target communities. In all three projects, a household was eligible for study if it contained at least one of the following subjects: 1) a pregnant mother, preferably prior to 5 months of gestation, 2) the subsequent infant of a target pregnant mother, 3) a preschooler (approximately 18 months), or 4) a school-aged child (7 to 8 years). Data were collected on the individual subject, aspects of the subject's household, and, when the child was the subject, on the child's biological parents. Preschoolers and schoolers were followed for one year, while pregnant mothers and infants were followed, in the case of Mexico, until the child reached eight months of age. Because many households contained more than one type of subject, some households were followed for periods exceeding one year.

Methods of Data Collection

Each of the seven general areas of research was supervised by a *Jefa de Area*: food intake, anthropometry and BMR, social performance and productivity, laboratory, psychology and morbidity. The following provides a summary of the data collection methods for selected data areas. (For more information, see Allen et al. [1]). Data collection occurred during the period January, 1984 through May, 1986.

The Community Census and Household Composition

A community census was completed for each of the six study villages. The census provided a basis for recruiting families into the study, demographic information on individuals and households, and data on the population of study villages. Information collected on every member of every household in the communities included name, sex, position in the family relative to household head, birth date (and method of documenting birth date), birthplace, principal occupation, and ability to read and write.

The household interviews were conducted by teams of two fieldworkers; one member of the team asked the questions (usually of the female household head), while the other recorded responses. The fieldworkers were high school students from a nearby town, who were trained in the procedures for conducting the interviews. The completed forms were reviewed by the supervisor, and, as necessary, households were revisited to fill in missing data. When birthdates were not verified in the initial visit the Area Chief visited the family to explain the need for accurate birthdates. This usually resulted in her viewing the available birth records. If none were available, this was noted on the census file. At the end of the project, a re-census was undertaken to update the original household data.

Daily Food Intake Data

Food intake data were collected in order to measure the nutrient intake and food patterns of target subjects within households. In addition, household food intake can be estimated from the amount of food in household recipes plus non-recipe foods consumed each day.

Data Collection

It is generally accepted that there is no perfect method for the measurement of food intake. The method chosen was adopted after considering: i) meal patterns in the communities and the percentage of daily intake consumed at each meal, ii) the amount of cooperation that could be expected from the respondents, iii) the number and cost of interviewers required, and iv) the accuracy of the method. The latter was tested by a series of validation studies [1]. The method combined recording by subjects, weighing by interviewers, and recall by mothers.

The procedure called for a three day period each month to capture 48 hours of diet information. Interviewers were conducted in the homes of study participants, with the female head-of-household as the respondent. If it was not possible to conduct the second recall interview in the subsequent 24 hours, it was rescheduled for the appropriate weekday of the following week.

Diet data were collected in somewhat different manners during three combinations of recording form and interviewer type. From January through September 1984, information was recorded on 1) attendance of individuals at meals (including ID and whether the individual ate); 2) list of non-recipe foods and ingredients in each recipe consumed that day (INNSZ food codes, weights, and form of ingredients); and 3) individual consumption of non-recipe and recipe foods (grams of the item consumed).

To permit the calculation of household food intake, a modified dietary data collection form was introduced in October, 1984. A new section on the proportion of recipes consumed by the household during the 24-hour period was introduced. This section helped interviewers to record difficult situations such as the use of leftovers and portions of prepared recipes left over at the end of a collection period. The form was also modified to permit easier data recording and data entry. It was used until the end of data collection in May, 1986.

During 1984, diet data were collected by high school "auxiliaries." The auxiliaries underwent an intensive training period of one-to-two months duration, supervised by trained, licensed nutritionists. During this time, they learned all phases of methodology, which until October 1984 included hand-calculation of the weights of foods consumed by individuals. The auxiliaries were rotated among households. In January 1985, trained nutritionists replaced the auxiliaries. These interviewer changes were a part of a general reorganization of the project to raise the interest level of both the staff and the respondents. The Area Chief for Diet was Elsa Molina.

The two changes in dietary protocol were associated with changes in mean energy intake (see Chapter 20 of the previous report by Allen et al. [1]). However, the change in data collection form was also associated with the Fall harvest when energy consumption normally does increase. All analyses presented in this report come from the new diet form (October, 1984 to May, 1986), and most are restricted to the final protocol period of January, 1985 to May, 1986.

The entry of diet data occurred at *Salud Publica* in Mexico City. These data were entered using a data entry program that provided data entry fields, necessitated double entry of data, and prompted correction of keypunching errors. An error-checking team at Solís compared keypunched data with the original forms as an additional data quality check. Finally, an extensive, computer-aided error-checking occurred at Connecticut which focused on range checking, recipe matching, and food matching. When errors were detected, these were flagged and returned to Mexico for subsequent correction.

Diet Variables and Nutrient Conversion

The initial Mexico CRSP nutrient variables were calculated using the INNSZ food conversion tables [2]. The INNSZ data base contains values for the following: edible portion (the edible proportion of each food) and energy, protein, fat, carbohydrate, calcium, iron, thiamin, riboflavin, niacin, ascorbic acid, and retinol. These data are based on food composition analyses done at INNSZ, with additional values in the INNSZ tables derived from the food composition tables of INCAP (Central America), INNE (Ecuador) and FAO (UN Food and Agriculture Organization). To the INNSZ base we (L. Allen at the University of Connecticut) added the nutrient content of an additional 67 foods. Of these, 25 were prepared foods, such as cooked beans, cooked pasta, scrambled eggs, etc. An average "recipe" was calculated for each based on a random sample of about ten recipes from the study, and the nutrient content was then calculated from the recipe. An additional 28 foods were condiments, teas, and spices. These nutrient values were obtained from the USDA Handbook 8. Later, Anne Black (a doctoral student at the University of Connecticut) added values for zinc, iron, fiber, and phytate (from the USDA Handbook 8) to the expanded INNSZ table [3,4].

The INNSZ conversion tables were used to calculate the nutrient content of each food eaten. Also, Dr. Black also created several measures of iron and zinc bioavailability [4]:

- *heme iron* - which is much more bioavailable than non-heme iron and is approximately 40% of the iron in meat;
- *non-heme iron* - plant iron and about 60% of iron in meat;
- *available iron* - based on the presence of the iron enhancers ascorbic acid and meat, and assumptions concerning iron stores (which affect iron absorption)[5], but not accounting for effects of fiber or phytate on iron bioavailability;
- *molar phytate:iron ratio* - because phytates inhibit absorption of iron;
- *phytate:ascorbic acid ratio* - because ascorbic acid may ameliorate adverse effects of phytate on iron absorption; and
- *phytate:zinc ratio and (phytate x calcium/zinc) ratio* - to reflect the inhibitory effects of phytate on zinc absorption.

These food- and meal-based values were then summed to create "daily summaries" of individual intake. In addition, the total and percent of energy and protein from several food groups and foods was calculated in order to rank individuals on their relative intake of these foods and to describe food patterns across subjects and households.

To facilitate cross-project comparisons, Dr. Murphy at UC Berkeley developed an *International Food Composition data base* (INT Minilist)[6]. The Minilist is a reduced list of foods in which groups of foods with similar nutrient profiles are represented by a single food in that group with good information on a large number of nutrients (e.g., all fresh green chiles can be represented by jalapeño chiles). This method sacrifices some food/nutrient specificity, but permits information on a much larger list of nutrients than is possible in conversion tables with a large number of foods. Using the Mexico CRSP database, UC Berkeley calculated daily summaries of 40 nutrients. The Mexico project used these Minilist values for nutrients other than those in the expanded INNSZ tables, e.g. vitamin B_{12}, folate etc.

In the analyses presented in this report, the dietary data presented are summary measures of daily intake obtained by taking the mean for each individual over the period they were studied (usually one year). With the exception of pregnant and lactating women, intakes of individuals with fewer than 6-8 dietary recalls were coded to missing.

Anthropometry

Anthropometric data were collected on all members of target households, supervised by Dr. Julia-Beatriz Castillo, Area Chief for Anthropometry. Anthropometric data include weight (to 0.1 kg), height or length (to 0.1 cm), two circumferences (head, upper arm) and four skinfolds (triceps, biceps, subscapular, and suprailiac), each to 0.1 cm. Anthropometric data were taken in the Solís clinic for male and female heads-of-household once every three months, and for any accompanying children. In subjects' homes, anthropometric measures were taken as follows: i) adults, once every three months, ii) children, weight once per month and other measures every 3 months, iii) infants, at 8 and 30 days, and then monthly. Measurements were taken of pregnant and lactating women, either in the clinic or at home, once per month. Newborns were measured at the Solís clinic. Additionally, all household members were measured in the home once at the end of the study.

Using a FORTRAN program obtained from the Centers for Disease Control (Chapter Five), children's weights and lengths were used to calculate percentiles and Z-scores based on their age at measurement.

Morbidity and Health Status

Morbidity Monitoring

Morbidity data, supervised by Drs. Homero Martinez and Alfonso Mata, were collected weekly on every member of the study households, using the following procedures:

- two members of the project staff (a physician and a community health aide) visited the household and interviewed the lead female;

- the opening question in the structured interview was, "Does anyone in the family have a health problem today or is anyone sick?";
- an affirmative answer activated a sequence of questions about the individual experiencing the problem. The women were asked to describe the signs and symptoms, and, for each of these symptoms, the day it started was ascertained. The physicians then probed for additional signs and symptoms. They also asked questions about the degree of incapacity, changes in appetite and any treatments that were being used, and the ending date of any illnesses recorded as being present on the previous week's visit;
- the physician conducted a brief examination of the sick person to confirm the presence of the reported signs. The weekly morbidity monitoring did not include chronic illness. This was determined by a clinical history and physical exam.

The standard questioning procedure was followed throughout the duration of the project. However, beginning in August, 1985 an additional question was added to the end of the protocol to probe for episodes that had occurred and been resolved between weekly visits. This addition permitted an assessment of the number and types of episodes that were missed when questioning was limited only to signs and symptoms that were present on the day of the interview [1].

The raw data on signs and symptoms were recorded on the interview forms in the colloquial Spanish used by respondents. Then they were coded, by the project physicians, using a list of 99 sign and symptom codes, developed by the medical staff. These codes were then collapsed into six "illness categories": (i) *fever* (including elevated temperature, chills and not feeling well); (ii) *gastro-intestinal* (including nausea, diarrhea, vomiting; dysentery, tenesmus, dehydration, hyperperistalsis); (iii) *upper respiratory* (including inflamed throat, sore throat, dysphonia, nasal congestion; phlegm, painful swallowing, inflamed pharynx, inflamed, enlarged or purulent tonsils; dry or productive cough, and difficulty in swallowing);(iv) *lower respiratory* (cough, chest pain, bronchitis, abnormal lung sounds, lung stertorous; (v) *common cold* (flu, common cold, clear or mucous nasal discharge; and (vi) *other.*

Clinical History and Physical Examinations

All subjects were interviewed and given a physical examination to obtain information on familial health history, their own past history and current health status. Subsequent interviews and exams were done for the purpose of monitoring health status during the course of the study. The physical examination included recording of vital signs, and data on the nose, throat, chest, abdomen and genital system, as well as assessment of vision, hearing, neurological status, limbs, rectum, and clinical signs of nutrient deficiencies. Specific problems identified in the examination were also noted.

The first physical was conducted on entry into the study. Adult men, non-pregnant women, school-age children and preschool children were re-examined every three months. Pregnant women were seen every month, a schedule that continued through the first six months postpartum. Infants were also examined once a month. Infants born in the Solís clinic were given their first physical within 12 hours of birth, while those born in the communities were first seen within 30 days of birth. All of the interviews and examinations were conducted at the clinic in Solís by a project physician.

Laboratory Analyses

Several categories of physical specimens were taken from subjects. These included samples of feces, urine, blood, and breast milk. Laboratory work was supervised by Margarita de Mata Palmiera. Further details of the plasma and milk analyses are provided in Chapter Eight.

Fecal Samples

Fecal samples were taken every three months from preschoolers, schoolers, and non-pregnant/non-lactating women (NPNL); at five and eight months of pregnancy; at one, three, and six months of lactation; at six months for infants; and at the start and end of the study for adult males. On arrival at the lab in the Solís clinic, feces were visually examined for consistency, mucous, and parasites. A microscopic analyses of cysts, eggs, and leukocytes was conducted on a diarrheal samples. A semi-quantitative analysis of the parasite load of each individual was achieved by centrifugation and flotation of protozoan cysts and helminth larvae with zinc sulfate.

Urine Samples

Urine samples were taken at the start and end of the study for adult males; every three months for NPNL women; at five and eight months of pregnancy; and at one, three, and six months of lactation. Urinalysis included i) smell, color, density, and pH; ii) semi-quantitative measures of protein, glucose, ketones, bilirubin, nitrites, and blood; iii) semi-quantitative description of cells, filaments, and crystals; iv) the presence of *E. vermicularis*, *Trichomonas*, or *Candida*; and v) bacterial counts by plating. Additionally, during 1984 pregnancy tests were made on urine samples from target mothers "at risk" of becoming pregnant based on their age and date of last delivery. This was done to increase the number of pregnant women enrolled in the study.

Blood Samples

Blood and plasma samples were taken once on exiting subjects with the exception of infants. In addition, samples were taken at five and eight months of pregnancy, and at three and six months of lactation. Hematological measures on whole blood, made with a Coulter Counter at INNSZ, were red and white cell counts, hematocrit, mean cell volume (MCV), meal cell hematocrit concentration (MCHC), and differential count. Plasma samples were analyzed for ferritin (Ferrizyme kit, Abbott), and prealbumin, complement C_3, transferrin, and IgA by laser nephelometry. A subset of plasma samples was studied for T-rosettes and blastoid transformation. T-rosettes and blastoid transformation were measured only on preschoolers and schoolers as they left the study, and for lactating women at six months. In addition, folate and vitamin B_{12} were analyzed by radioassay in a subset of plasma samples (Chapter Eight).

Breast Milk Samples

Milk samples were collected at one, three, and six months of lactation. Initial plans to sample colostrum were not realized due to objections of the mother. The fat content of the breast milk samples was estimated by centrifugation (the "creamatocrit" method). Dr. Black analyzed the samples for vitamin B_{12} [4].

Psychological and Behavioral Data

Psychological and behavioral data were collected on all target individuals. The development, pre-testing and supervision of data collection on cognitive performance in adults and school children was under the direction of Dr. Gordon Finley, Professor, Florida International University. Dr. Tiffany Field, Professor, University of Miami, had parallel responsibilities for the observational components of school child testing, and all aspects of infant and preschool testing, including observation of mother-infant interactions. The Area Chief for Psychology was Eulalia Martinez, who has a *licenciatura* in psychology from the University of Morelos, and had completed a year of post-graduate work at the *Universidad Nacional Autonoma de Mexico* (UNAM).

Infant Psychology Instruments

Infant psychology consisted of the Brazelton Neonatal Behavior record, the Bayley Scales of Infant Development, and observations of Mother-Infant Interaction.

Brazelton Neonatal Behavior Assessment Scale. The Brazelton Neonatal Behavior Assessment Scale (BNAS) is an assessment instrument developed by Dr. T. Brazelton, which uses

> "behavioral items to assess the infants' responsiveness to external stimuli, his motor organization and his ability to modulate his state of consciousness. These behavioral items reflect the integrity of the infant's central nervous system, and the infant's capacity to elicit caretaking from an adult" [7].

The examination consists of 28 behavioral items each scored on a 9-point scale, the items being selected to measure "the coping capacities and the adaptive strategies of the infant)"[7]. In addition, the BNAS contains 20 reflex items, which assess the neurological responses of the newborn. These are scored by the trained examiner, who attempts to elicit neonate responses under neutral ambient conditions of quiet, moderate light, and comfortable temperature. The examination includes assessments of the newborn's reflexes, movements, reactions to light, and sound and tactile stimulation, as well as a few items on the tester's global evaluation of alertness, motor tone and maturity. The examiner in Mexico was Ms. Martinez, who was trained in the administration of the BNAS at the University of Miami under the direction of Dr. Tiffany Field. The data were coded using the system developed by Lester [8]. This produces seven sub-scales: 1) *habituation*, 2) *orientation*, 3) *motor development*, 4) *range of state*, 5) *regulation of state*, 6) *autonomic stability*, 7) *reflex score*.

The Brazelton Neonatal Behavior Assessment Scale was given once, usually within 24-72 hours of birth. In a small number of subjects, who were not born in the health clinic in Solís, the examination was administered when the infant was brought to the clinic for a first medical examination. This event occurred between 8 and 28 days after birth.

Bayley Scales of Infant Development. The Bayley Scales of Infant Development (Mental and Motor Scales) measure a number of characteristics that may be affected by marginal malnutrition. The *mental scale* is "designed to assess sensory-perceptual acuities, discriminations and the ability to respond to these; the early acquisition of 'object constancy' and memory, learning and problem solving ability; vocalizations and the beginnings of verbal communication and early evidence of the ability to form generalizations and classifications, which is the basis for abstract thinking" [9]. The *motor scale* is intended to "provide a measure of the degree of control of the body, coordination of the large muscles and finer manipulatory skills of the hands and fingers. As the Motor Scale is specifically directed toward behaviors reflecting motor coordination and skills, it is not concerned with functions that are commonly thought of as 'mental' or 'intelligent' in nature"[9].

In the CRSP study, for the Mental Scale at 6 months of age, a total of 51 items from the original scale was utilized. These were numbers 40 - 90 inclusive. From the motor scale a total of 26 items from the original scale was selected -- those numbered 14 - 40, inclusive.

The Bayley Mental and Motor Scales were administered once at six months of age. The assessment of the child's performance by the psychologist, the Infant Behavior Record, was also filled out in conjunction with the administration of the Bayley. The full battery of testing procedures on the infant at six months of age was scheduled to be administered in a single session. The examiner began with items of the Bayley Mental Scale, followed by the items of the Motor Scale. The items of the Infant Behavior Record were filled out before the psychologist proceeded to the mother-infant interaction. If the infant appeared to be very sleepy or was crying hard and couldn't be readily calmed, the examiner stopped the testing procedure and returned on another day.

Mother-Infant Interaction. At the ages of 3 and 6 months, the interaction of the infant with its mother was investigated by Mexico CRSP psychologists employing a protocol developed by Dr. Tiffany Field of the University of Miami. For this testing procedure, the mother was asked to sit on a bed or chair and to hold the infant facing her, supporting the baby's upper body and head. The psychologist asked the mother to play freely with the baby. The observer sat at a ninety degree angle to the mother and infant and recorded their behaviors on a form that included the items described above. The research protocol called for 30 one-minute periods of observation and recording (10-seconds of observation and 5-seconds of recording). For each observation period, the presence or absence of nine infant behaviors was coded: 1) looking at the mother, 2) smiling, 3) cooing or vocalizing, 4) laughing, 5) yawning, 6) knits brow, 7) fussing, 8) bicycling limbs, 9) and squirming. Similarly, eight maternal behaviors were coded: 1) looking at infant, 2) smiling at infant, 3) vocalizing to child, 4) touching the infant, 5) moving the infant's body and limbs, 6) imitating infant's sounds, 7) playing games with infant, and 8) shows infantized behavior.

Preschool Children Psychology Instruments

The Bayley Scale of Infant Development was also used to collect data on psychological characteristics of preschool children.

The Bayley scales were administered to preschool subjects at three ages: 18 months, 24 months and 30 months. This schedule was generally followed, but a number of factors affected the exact date of testing. Children were not tested when they were ill, as judged by the presence of fever or the mother's report that the child was sick to the point that activity was altered. The most common reason for a testing delay was the temporary absence of the family from the house or community. A third factor, which mainly affected testing at 18 months was temporary non-availability of a trained examiner, as a consequence of staff turnover.

Although the full battery of testing procedures was designed to be administered in a single session, with some children the examiners needed a first visit simply to establish rapport with the child, and testing would be delayed for a few days. Most testing was conducted in the patio of the children's home; in bad weather the testing took place inside.

The Bayley Mental Scale. The complete scale, for use from birth to 30 months of age, consists of 163 individual items, graduated from most simple to increasingly more complex or advanced responses. As the scale includes items for testing very young infants, there were items in the battery that all 18 month old children would be expected to pass. Therefore, for greater efficiency of test administration and recording, Dr. Field eliminated the simplest items, selecting 54 consecutive items for use at 18 months and adding an additional 10 for children aged 24 and 30 months. In the Bayley Scale format these are items numbered 100 to 153 and 100 to 163 respectively.

The Bayley Motor Scale. Parallel to the Mental Scale, the items of the motor scale are structured in increasing order of difficulty based on developmental norms established with a large U.S. sample. The full battery, applicable from birth to 30 months consists of 81 items. For the application in the Solís sample, Dr. Field reduced the total number of items, selecting those that are appropriate for the 18 - 30 month preschooler. For the 18 month old, the exam included 12 items (numbers 47-52, and 57-65 in the original Bayley format). At 24 months an additional 5 items were added, including numbers 47-52, 57-61, 65, 68, 70, 71, 73 and 75 of the original format. At 30 months, 22 items were included - numbers 47-52, 57-61, 65, 68, 70, 71, 73, 75-79, and 81 from the original format.

School-age Children. The psychological data on school-age children cover two main categories: cognitive development and social emotional functioning. For the child of seven to nine years, the data presented in this monograph were collected with a cognitive test battery and with teacher ratings of children's characteristics.

Cognitive Test Battery. The tests of cognitive functioning were drawn mainly from the WISC-R, Wechsler Intelligence Scale for Children [10], with some additional measures. From the WISC-R the following components were used: (i) *digit span* task, in which the subject is asked to repeat sequences of numbers, first in the order they are presented to the subject, then in reverse order; (ii) a *block design* task that requires the subject to copy designs presented pictorially with a set of blocks; (iii) an *arithmetic* test, in which the problems to be solved are presented in verbal form; and (iv) a *maze* test, which requires the subject to trace a path from the center of a maze to a final outlet.

Cognitive test components from other sources were: (i) *Raven's Progressive Matrices* task, in which the subject is presented with a pattern from which a piece is missing. The task is to complete the pattern by selecting from a set of different shapes the one shape that is correct [11]; (ii) the *Peabody Picture Vocabulary Test* [12], in which the subject is asked to identify pictures that illustrate specific words; and (iii) an *Attention Span* task, in which the subject is asked to place a mark across rows of lines, working as rapidly as possible. The performance is scored as the amount of time required to "cross off" all of the lines, and the number of lines crossed per second.

The cognitive tests and teacher ratings of school age children were administered twice. The first measurements were taken in early 1984. The second measurement series took place in the fall of 1985, 15 to 18 months after the original measurement.

Testing was conducted in the schools, in rooms where the testing could be conducted without distraction. Only the test administrator and the subject were present. Testing took place during the school day, and the children were brought from the classroom to the testing room. Children who were not enrolled in school were tested in their home.

Teacher Rating of Child Characteristics. The teacher ratings of the school-age children included two checklists. The first, based on the Behavior Problem Checklist developed by Quay, is a list of 50 characteristics, such as *cries easily*, *poor attention span*, *often sad*, and so forth [13]. The child's teacher is asked to mark all of the items that apply to the child.

The second checklist, developed by Buck, consists of 25 additional characteristics that are explicitly designed to provide a basis for an *introversion-extroversion* score [14]. For each characteristic the teacher is asked to rate the applicability of the trait to the child, using a 5 point scale. At the end of each school year, the teachers were given forms for the Quay and Buck instruments to be filled out for every child in their classroom who was a target child in the CRSP study.

Adult Psychology Instruments

The psychological data on adults was limited to an assessment of cognitive performance, using a test battery that parallels the testing procedures with school children. However, in the case of women who were mothers of index infants and preschool children, the mothers' social-emotional behaviors in the social-interaction tasks were also assessed.

The cognitive test battery was applied once to each adult in the study. Efforts were made to conduct the testing within a few months of entry into the study. In a few cases, however, mainly with men who are frequent migrants, the testing could not be completed until near the end of the family's participation in the study.

All testing of adults was carried out in the home. The preferred procedure was to test both parents in the same visit, working with the mother first, then the father. The psychologists usually went to the house in a team of two. One individual administered the test, while the second took care of small children, talked with other adults and generally tried to prevent distractions and interruptions to the testing. In some homes it was possible to carry out the testing in a separate room. In many cases, however, the testing was done in the patio.

Data Collection and Quality Control

Data collection procedures were supervised by Ms. Eulalia Martinez, who holds a licenciatura in psychology. She had the primary responsibility for recruiting and training the staff who administered the psychological tests and conducted the observational studies. The field staff consisted of university students in psychology who had completed all requirements for their *licenciatura* except for the thesis. After didactic training sessions, field training took place in the Solís Valley but not in the study communities. For the cognitive test protocols, the following training procedure was used: (i) the chief psychologist administered the test to a subject child while the fieldworkers observed and filled out the data recording sheet; (ii) the fieldworkers' coding was reviewed and problems were discussed in the full group; (iii) individually, fieldworkers administered the test to subjects, while the others watched and filled in their code sheets. The coding was then reviewed and discussed.

For the cognitive tests on preschool, school-age and adult subjects and the mother-child observation studies, tape recording the interviews was an appropriate means of assessing quality of data collection. As each new procedure was put into place, or as new fieldworkers began working independently, tape recordings of every interview were made for at least two months.

In the case of mother-child interactions, all interviews were tape-recorded throughout the project in order to code verbal behavior.

The Area Chief reviewed each tape, checking the manner in which fieldworkers gave instructions and asked questions. To the extent possible, the coded responses were also checked.

A primary mode of maintaining data quality was observation of testing by the Area Chief. Throughout the study she regularly attended testing situations, including the playground and classroom observations. In turn, she reviewed her own testing procedures by comparison with those of Dr. Field's assistant, both in Miami and in Solís. When problems were identified, the issues were discussed with the individual fieldworkers or, as relevant, in group meetings of the psychology field team.

Preschooler-Mother Activity Data

Kelley Scanlon, a doctoral student at the University of Connecticut, and four Mexican colleagues collected extensive observational data on 41 target preschoolers and their mothers [15]. The activity of each mother-preschooler pair was measured each hour between 8 and 6 PM by actometer, and by spot and 10-minute observations. Each subject pair was observed on 13 days (for a total of 143 spot and 10-minute observations). The observer recorded

> "*locations*, *body positions*, *activities* (including quality descriptions of activities such as play, child care, etc.), *affect*, and *social interactions* of participants with each other and with others in the home, as well as the *presence of other individuals* who were not interacting with the participants" [15].

Observers were accompanied by Dr. Scanlon during the early months of the study with both persons recording observations and then comparing codings. Inter-rater reliability was calculated for 650 observations and found to be greater than 95%.

The observational data were later coded for data entry using a complex coding system. These data were then collapsed into several categories. Summary behavior measures were obtained by calculating the percent of occasions on which the behavior was observed during all observation days.

Social Data

Socio-economic Status

A standardized two-part interview was administered to obtain data on socio-economic characteristics. The first part concerned characteristics of the dwelling, including the flooring, roof materials, walls, etc., as well as ownership of household and agricultural goods. The second part of the interview focused on migration and wage labor of household members.

The female household head was the primary informant for this interview, although in many cases it was also necessary to interview the male household head to obtain data on economic resources and migration activities. The data were collected twice from the families, once at entry into the study and again at exit from the study or after one year, whichever occurred first.

The fieldworkers for this interview were young men and women with either secondary school or high school-level training, all of whom came from the nearby town of Temascalcingo. It was felt that it would be best not to use interviewers from the villages, but that it was important for interviewers to be familiar with the local culture. Young people from the nearby municipal center seemed appropriate because many of them had experience with life in the villages (through friends and relatives), but they were not directly neighbors of the families they were to interview. The training of the interviewers included discussion of principles of interviewing, item-by-item explanation of the purpose of the questions and practice interviews. Throughout the data collection period a sample of each fieldworkers' interviews were tape recorded to permit checking the questioning procedures and the correctness of his/her recording of responses by Ms. Luz Maria Meneses, the Area Chief.

Despite the "monetarization" of household economies, particularly as a result of wage labor, most respondents either cannot or are reluctant to provide an accounting of their economic situation in terms of cash income. The management of household finances is mainly by men, who give their wives money for purchases. Ethnographic interviewing early in the project demonstrated that questioning about income violated cultural norms and could not be used as a basis for assessing socio-economic status. As a result, our assessment of economic status is derived from data that *reflect* economic resources.

Specifically, we inventoried household characteristics that reflect economic resources expended on household goods and housing conditions. From these two scales were constructed: a material-style-of-life scale (MSL), based on ownership of household goods, and a house value scale (CASA), based on characteristics of the physical structure in which the family lives. The selection of items for the MSL scale was derived from ethnographic work to identify items that represented different degrees of household material conditions. The items in the scale are: ownership of gas stove, television, radio, tape recorder, tape player, food blender, electric iron, sewing machine, wardrobe for clothes storage, kitchen table and chairs, dish cabinet and refrigerator. The items in the CASA scale are: composition of the floor, roof and walls, whether the walls are plastered and painted, the number of rooms, number of windows, number and type of doors, and number and type of beds.

For the MSL scale, each item was assigned a value based on the market price of the item in 1983. For the CASA scale, each item was coded on a three-point scale based on level of desirability. For example, a door frame without a permanent door had a value of 1, a wooden door received a value of 2, and a metal door was assigned a score of 3. As might be expected, given the differences in scoring procedures for the two scales, the CASA scale had a normal distribution, whereas the MSL was skewed to the left, with a long "tail" of the few families with a considerable number of possessions.

Because the MSL and CASA scales were strongly correlated, they were combined into a single measure in which each scale was given equal weight. To construct the combined scale, the households were first ranked separately on the MSL and CASA scales; then the households' ranks on each scale were summed, to create a composite SES measure. The results from the first and second interviews were then combined to create a mean SES measure.

Agricultural Activities and Productivity

This protocol was designed to collect information on farming practices and productivity. It included information on land holdings, types of crops planted, labor and cash inputs into planting, field maintenance and harvesting, harvest yields, and on non-farm income-earning activities of the household head and other household members.

The first interview, which was usually conducted with the lead male, covered the harvest of the previous agricultural season, (October through December). Occasionally, when the lead male was a migrant, the female household head provided the information. The second interview concerned preparation of the field and planting, and the third interview focused on weeding and irrigation. The final interview returned again to harvest activities.

The agricultural activity interview was conducted by a small team of fieldworkers, a subgroup of those who were trained to carry out the socio-economic interviews. While many of these interviews took place in the respondent's house or patio, they were occasionally carried out in the agricultural fields. In either location fieldworkers were instructed to look for observable features to confirm the respondents' answers.

Social and Cultural Characteristics

This interview schedule, which was administered once to each lead male and lead female, was designed to gather information on social behavior, values, and aspirations, as well as knowledge, media exposure and related features. The interview included questions on: i) aspirations for children's education and occupation; ii) frequency of travel outside the community; iii) radio and television exposure; iv) participation in family and community social activities; v) extent of utilization of social programs; and vi) knowledge of community and external affairs.

As with the economic data collection, the interviews were conducted by young adults from the nearby municipal center who had secondary or high school level training and who were closely monitored by the Area Chief in charge of social data.

Monitoring the Quality of Social Data

The three areas of social data were subject to the same procedures for data quality control. At the end of each day the interviewers returned their completed forms to the Area Chief for review. The sample of tape recorded interviews was also checked on a daily basis. Problems of missing data, highly unusual values or other apparent errors were discussed the following day with the fieldworkers individually. The fieldworkers then returned to the respondents to obtain additional information or make the corrections. In some cases, for example when the Area Chief felt there might be a problem of rapport between the interviewer and the respondent, she went back herself to collect the correct information.

Coding the Social Data

The data from the three social data instruments were transferred to code sheets. The decision to use an intermediate coding procedure was based on the following consideration: (i) many questions were open-ended or included an option to record an alternative answer; and (ii) because the distribution of responses could not always be anticipated, questions were designed to maximize detail, with the expectation that the first level of data reduction would occur in transferring the responses to code sheets.

To design the coding categories, a sample of completed interviews was reviewed and tabulated. Decisions about combining items into a single code were based partly on frequencies and partly on logical or cultural considerations. To preserve richness of information, combining items into a single code was kept to a minimum. All coding was done by the Area Chief. Approximately 50% of the socio-cultural interviews, 25% of the socio-economic and 10% of the agricultural interviews were also coded by principal investigators. There were virtually no coding disagreements between the coders.

Household Appearance/Maternal Management Measures

The study design of the full CRSP called for measurement of sanitation and hygiene conditions and practices. To the extent possible, projects were also encouraged to obtain data on maternal care-giving and related characteristics of the household environment that may affect developmental outcomes -- biological and social -- in children. In the Mexico CRSP the concept of "maternal management" was developed as a means of encompassing both the sanitation-hygiene component and indicators of the care-giving environment. The specific indicators consisted of a set of measures of the appearance of the physical environment and household members.

Developing the Observation Protocol

The major methodological challenges to obtaining valid and reliable measures of physical appearance as indicators of maternal management include: (i) establishing criteria that are culturally appropriate and reflect local or *emic* standards rather than external perceptions; (ii) collecting observations in an unobtrusive manner that minimizes the likelihood that mothers will change their usual behavior to accommodate social expectations; and (iii) obtaining enough observations to represent usual conditions.

The first step in constructing an observation checklist of physical appearance of the household and of key members was to conduct ethnographic research to obtain information on local perceptions about cleanliness. Information about which parameters were most readily observable, and the range of values and characteristics one could expect to find within the villages was also acquired.

Meetings were then held with the project field workers, during which they were asked to identify households and individuals who typified different levels of neatness and cleanliness in the community. The specific characteristics that led to these evaluations were explored at length. We also ascertained that field workers could distinguish between the neatness/cleanliness indicators and levels of socio-economic status. That is, the concepts of a "poor but neat and clean" household, and "well-furnished but unkempt" household were both relevant, and apparent to the field research staff.

After several pretests, an observation check list of 30 items was devised, which required observers to rate conditions of the patio, living quarters (including kitchen) and the physical appearance of key household members. Some items were scored simply as presence or absence (eg. waste, trash). Others involved a three point scale of judgment (good, average, poor) and a few items required a four point differentiation.

Observations were directed at both environmental conditions and "key" individuals -- the mother, a preschool age child and a school-age child. In households where the target child was a preschooler or an infant, the "young child appearance score" refers to that child. However, in households where the school-age child was the focus of study and a younger child was present in the household, the "young child appearance score" refers to a non-target child for whom there is not complete dietary and anthropometric data. The same generalization applies to the "school-age child appearance score."

Data Collection

All project field workers (nutritionists, physicians, psychologists, interviewers for social data, and social workers) were trained in the use of the checklist, and the instrument was incorporated into routine data collection procedures. At each of their visits to a study household, the staff member was expected to complete the standard observation protocol. Over the course of a year in the study, each household would have approximately 24 observations made by a nutritionist, as well as a number of observations by other project personnel.

Although most of the staff participated, to some degree, in the initial protocol development, all were given a short training session in the use of the protocol. All training was supervised by the Area Chief for social data, who also had responsibility for periodically checking the completed data sheets.

Data Coding and Construction of Variables

In order to construct indices that summarize the multiple measurements, several analyses were undertaken:

- for each household, the mean for each of the items in the observation protocol was calculated;
- frequency distributions and descriptive statistics of the mean values for each item demonstrated that nearly all of the variables had a large range and little skewness. The main exception to this generalization was the observation of "animal excrement on the floor inside the house." In most houses observers recorded the presence of excrement most of the time;
- a principal components analysis was carried out on the environmental variables. With the exception of "animal excrement inside the house," all variables loaded on the first factor at a correlation of 0.68 or greater. Based on this finding, it would be justifiable to construct a single "environmental cleanliness score." However, the ethnographic data suggested that "inside environment" (within the house) and "outside environment" (the patio) could be culturally, as well as logically distinguished. Therefore, two environmental scales were created, one for "inside appearance" and another for "outside appearance."
- daily scores are calculated by adding the means for each item and multiplying by 100. Higher scores indicate better appearance;
- summary measures for *maternal appearance* (MAS), *young child appearance* (YCAS) and *school-age child appearance* (SCAS) were calculated as the average of all ratings, on a three point scale, by all observers, multiplied by 100.

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Chapter Four.
The Solís Valley Diet and Food System

The 'Traditional' Central Mexican Diet

Today's diet in rural, central Mexico is an admixture of Indian, Spanish, and contemporary foods. The roots of this diet lie in pre-Columbian Mexico when Indian agriculturalists consumed a diet that was based on ground maize, beans, squash, tomatoes, chiles of many varieties, the domesticated turkey, and wild foods such as *nopales* (cactus leaves) and wild game. *Tortillas* and other dishes made from ground maize were the major sources of dietary energy, while other foods provided varying amounts of other nutrients.

The Spanish Conquest brought new European foods (such as wheat, barley, chicken, and cow's milk), and new ideas concerning the preparation of foods, and beliefs about the quality of foods (such as 'hot/cold' beliefs in their healthfulness). The expanding Spanish empire and European contact with non-European peoples also resulted in the introduction of foods from around the world, including potatoes from Peru, rice from Asia, spices from the Far East, and coffee from the Near East.

In recent years, the expanding Mexican and world economies have introduced still more new foods, technologies, and ideas. Improvements in the transportation system and the expansion of the commercial food network have increased the availability of fruits and vegetables during the year, and introduced many new foods, including prepared foods. These have diversified the local diet. Modern technologies have created new methods of food preparation. Fresh ideas concerning the worth and qualities of foods are introduced to the valley via television, radio, and urban contact. Taken together, these influences are changing the rural, central Mexican diet. Nevertheless, traditional ideologies of food, subsistence agriculture, and other social forces have conserved many of its traditional aspects, resulting in a diet not fundamentally different than that of the Otomí and Mazahua residents of the Solís Valley in 1492.

Food Preparation, Core Foods, and Meal Structure

In 1929, Margaret Redfield observed that "Tepoztecan cookery takes its character from two simple implements, the grinding stone, *metate* (*metlatl*) and the hand stone, *metlapil*, (*metlapilli*)" [1]. To complete the technological list, she might have added the clay pot (*olla*), ceramic griddle (comal), and wood-fired hearth. From this technology arose a rich cuisine based on grinding, boiling, and stewing. *Sopas* (soups and 'dry' soups made of pasta and rice) and stews of various types constitute a major class of dishes in central Mexican cuisine. *Salsas* (an uncooked sauce composed of several fresh vegetables), *moles* (a cooked sauce made from chiles and a variety of ingredients), and *atoles* (flour-based drinks, usually made from *masa*, water, and sugar) were once based on grinding technology. A few decades ago, grinding was the principal activity of many women in central Mexico, much of the day being spent in grinding the *nixtamal* (maize soaked with calcium carbonate) to create *masa*. This *masa* was then made into *tortillas* that were cooked on a clay *comal* over a wood-fired hearth.

In recent years, modern technology has transformed central Mexican cooking. *Nixtamal* is now ground at commercial maize mills, and the *tortillas* are promptly cooked for consumption during the subsequent few days. Electric blenders may aid the preparation of *salsas* and *moles*. Dried chile powders, rice and corn flour, and commercial *masa* may be purchased for use in cooking. Metal pots and the gas stove often replace *ollas* and charcoal fires for cooking. Despite this change, the essential qualities of central Mexican cuisine remain, the old model being retained with the addition of new ingredients and new modes of preparation. Table 4.1 shows the diet of a San Nicolas household during a 48-hour period. Their diet is more complex than that of most households, and contains somewhat more animal foods and vegetables. Nevertheless, the diet is typical in many respects. *Tortillas* are consumed at every meal. Most of the dishes are prepared by boiling or stewing. And, with the exception of lard, all of the foods are commonly eaten and fall within the dietary core of the Solís Valley diet.

Most food consumption in the target communities occurs at meals within the household environs. *Desayuno* is the early light morning meal eaten on awakening. In practice, *desayuno* is often an optional meal that is frequently skipped or composed of a few *tortillas* and coffee with a little milk and sugar. Other warm drinks such as teas and *atoles* (flour-based drinks) are also eaten at *desayuno*. The most commonly eaten foods at *desayuno* are sugar, *tortillas*, coffee, white and sweet bread, milk, cinnamon, onions, eggs, rice, and beans. Leftovers are also a feature of this meal.

Almuerzo is the mid-morning meal, and is more substantial and labor-intensive than *desayuno*. Hot drinks remain a feature of this meal, but white and sweet breads are less important. The most commonly eaten foods at *almuerzo* are *tortillas*, sugar, onions, eggs, coffee, beans, tomatoes, garlic, chiles, potatoes, rice, *pulque* (a mildly alcoholic beverage fermented from the sap of the *maguey* plant), and milk.

Comida is the most important meal of the day, and it is typically eaten in the mid-afternoon. Sugar, coffee, and milk are minor components of this meal. Bean, pasta, and *pulque* consumption are more common than in the morning meals. The most commonly eaten foods are *tortillas*, onions, tomatoes, garlic, *pulque*, beans, pasta, chiles, eggs, potatoes, *nopales* (cactus leaves), and green tomatoes.

Cena is the evening meal, and it is usually a light meal requiring little preparation. Leftovers often comprise a quick *cena*. *Pulque* consumption is less important than at either almuerzo or comida. Consumption of refined sugar is higher but milk is infrequently consumed. The most commonly consumed foods at *cena* are *tortillas*, onions, tomatoes, *pulque*, sugar, garlic, beans, chiles, eggs, potatoes, and *nopales*.

At these meals, a large number of different foods may potentially be consumed. In 4,226 recalls from January 1985 - May 1986, 338 different foods were reported. However, only a very few foods were actually eaten with much frequency by most households. Table 4.2 provides a list of 39 foods that were consumed by 50% or more households on at least 1% of recall days. [For each household, the frequency of consumption of the food was calculated as a percent of total recall days. Households were required to have at least 6 recall days.] The median in Table 4.2 represents the frequency of consumption of that food below which 50% of households fell. Therefore, tomatoes were consumed by half of the households on at least 60% of recall days, and 25% of households consumed them three out of four days.

Table 4.2 shows the most frequently consumed foods to be staples and ingredients in *salsas*. *Pulque* is eighth on the list, while chicken eggs are ninth and the first animal food eaten with any frequency. Chicken, the next most frequently consumed food, is eaten on just 11% of days by 50% of households. Milk is consumed with about the same frequency as chicken for 50% of households. However, at least 25% of households never consumed milk (or lean or fatty beef). Considering the amount of the food consumed (see Table 4.1) and the frequency of consumption, many of the best sources of several bioavailable nutrients are those foods that are consumed less frequently. The reasons for this pattern of food consumption lie in social constraints related to food acquisition.

Foodways: Methods of Food Acquisition

In addition to providing new foods, the Spanish conquest also brought about permanent changes in the mode of production of foodstuffs. Large tracts of the best land were incorporated into *haciendas*. In the Solís Valley, the indigenous population was obligated to work for the *hacendado*, which cultivated the fertile lands of the valley bottom, growing wheat, barley, and other cash crops [2,3]. Most of this agricultural production was exported from the valley, while the peasants were compensated with *hacienda*-grown maize that was used to supplement home production of food on marginal, hillside lands [2].

With the Revolution came land reform and the *hacienda* lands were distributed as *ejido*, each eligible peasant receiving a small allotment of community-controlled land to work as their own. These lands were protected under the Mexican constitution from private ownership, and were reserved for the use of *ejido* members. This *ejido* land forms the basis for most of the small-scale, household-based maize agriculture that now dominates the Solís Valley. Recent changes (January, 1992) in the Mexican Constitution have affected the status of *ejido* lands, and have the potential for producing far-reaching change in the valley during the next decades. The food consumed in the Solís Valley today comes primarily from three sources: i) subsistence agriculture, ii) food gathering, and iii) food purchases.

Table 4.1: Example of household meals for a 48-hour period (from Backstrand, 1990).

WEDNESDAY, MARCH 20, 1985

MEAL	DISH	INGREDIENT	WEIGHT (g)
Cena	*Chicharron*	*Chicharron*	1500
		Salt	7
		Serrano chiles	20
		Water	2000
		Bouillon cube	6
		Onion	10
		Tomatoes	135
		Green tomatoes	80
		Garlic	1
		Lard	10
	Salsa	*Serrano* chiles	15
		Salt	2
	Pulque		
	Tortillas		

THURSDAY, MARCH 21, 1985

MEAL	DISH	INGREDIENT	WEIGHT (g)
Almuerzo	*Chicharron*	(leftovers)	(25% of recipe)
	Atole	Rice flour	120
		Sugar	120
		Powdered milk	80
		Water	1500
	Coffee	Instant coffee	4
		Water	500
		Sugar	20
	White bread		
	Tortillas		
Comida	Fried eggs	Eggs	50
		Salt	1
		Lard	5
	Potatoes with *Nopales*	Potatoes	1000
		Nopales	1000
		Water	2000
		Salt	4
		Lard	20
		Onion	10
		Garlic	1
	Pulque		
	Tortillas		

Table 4.1 (continued): Example of household meals for 48-hour period.

FRIDAY, MARCH 22, 1985

MEAL	DISH	INGREDIENT	WEIGHT (g)
Cena	*Sopa de pasta*	Lard	15
		Pasta	200
		Onion	5
		Garlic	1
		Bouillon cube	3
	Tortillas		
Almuerzo	*Atole*	Rice flour	120
		Sugar	100
		Powdered milk	80
		Water	1500
	Beef with	Lean beef	500
	Potatoes	Water	750
		Serrano chiles	25
		Potatoes	200
		Green tomatoes	20
		Tomatoes	400
	Sopa de pasta	(leftovers)	(20% of recipe)
	Tortillas		
	White bread		
	Pulque		
	Coffee	Instant coffee	3
		Water	500
		Sugar	10
Comida	Beef with	Potatoes	500
	Potatoes	Lean beef	400
		Lard	20
		Water	1500
		Chiles *negro*	40
		Salt	4
		Garlic	1
		Bouillon cube	4
	Chilaquiles	*Tortillas*	1000
		Bouillon cube	4
		Lard	15
		Salt	4
		Serrano chiles	8
		Water	1000
		Cilantro	3
		Tomatoes	250
	Tortillas		

Table 4.2: Core foods from household diet recall data (January, 1985 - September, 1985). Quartiles for percent of recalls food was consumed (from Backstrand, 1990).

	1st Quartile	Median	3rd Quartile
Tortillas	100.0	100.0	100.0
Salt	94.9	100.0	100.0
Onions	83.3	91.7	97.4
White Sugar	67.3	88.5	97.9
Vegetable Oil	70.8	83.5	95.7
Tomatoes	47.8	60.0	73.9
Garlic	38.5	57.9	75.0
Pulque (alcoholic drink)	11.5	48.8	80.0
Chicken Eggs	32.6	47.8	61.5
Beans	35.3	45.6	58.3
Coffee	19.2	41.2	69.2
Serrano Chiles (fresh)	22.7	38.9	52.4
Pasta	21.4	33.3	43.6
Potatoes	18.8	28.6	38.2
Nopales (cactus leaves)	15.4	25.0	37.3
Green Tomatoes	11.1	21.9	35.6
Rice	9.6	18.8	28.6
Tomato Soup Mix	5.6	15.8	31.2
Cinnamon	2.9	12.5	27.8
Boiled Beans[1]	5.6	12.5	22.2
Chicken	5.0	11.8	19.2
Cow's Milk	0.0	11.1	35.0
White Bread	0.0	10.0	28.1
Quelites (wild green)	2.5	9.1	15.8
Key Lime	0.0	5.6	16.7
Pasilla Chiles (dry)	0.0	4.5	11.1
Bouillon Cubes	0.0	4.3	16.7
Squash	0.0	4.3	9.1
Fatty Beef	0.0	4.2	10.0
Jalapeño Chiles	0.0	3.8	11.1
Guajillo Chiles	0.0	3.0	10.0
Lean Beef	0.0	2.8	7.9
Soft Drinks	0.0	2.8	9.1
Masa	0.0	2.6	7.7
Dry Broad Beans	0.0	2.6	7.1
Fresh Broad Beans	0.0	2.6	6.2
Chicharron (pork rind)	0.0	2.2	5.9
Cilantro	0.0	1.9	6.2
Cascabel Chiles	0.0	1.7	10.2

[1] Boiled beans were occasionally coded separately from dry beans

Subsistence Agriculture

Most households in the six Nutrition CRSP communities are engaged in some form of subsistence agriculture. In 1984, 97% of cultivated lands were *ejido* [4], and approximately 80% of target households reported cultivation of *ejido* land. The size of these landholdings was small, the median being one hectare. Virtually all of the land was used for small-scale maize production, and most maize was grown exclusively for household use (only 19% of households reported sales of maize). Of this maize, 90% was for human consumption. Harvested maize is stored in the house for future consumption, and rates of storage loss are unknown. Almost half (45%) of the households produced insufficient maize to last the year. Most of these purchases occurred during the summer months just prior to the next maize harvest.

Many households also produce varying amounts of several other foods, the most important being chicken, eggs, beans, cow's milk, squash and squash blossoms, and fresh and dry broad beans [4]. With the exception of squash during the summer months, home-production of non-maize foods in the population was never more common than purchases of those foods.

Food Gathering

Gathering is an important source of vegetables in the Solís Valley diet. The only commonly gathered foods are *nopales* (cactus leaves) and *quelites* (a wild green). *Tunas* (cactus fruits) are also consumed when in season. Neither are typically purchased, and both are the most common green vegetables consumed in appreciable amounts within the valley.

Food Purchases

Most foods in the Solís Valley diet are purchased. For a sample of 88 households with 10 or more weeks of food use data (one week per month), forty different foods were found to be purchased by at least 10% of target households [4], and 24 foods were reported as purchased on a monthly basis by at least 10% of households: refined sugar, *pulque*, soft drinks, rice, white bread, sweet bread, pasta, chicken, beef, carp, *limon* (bitter lime), bananas, vegetable oil, eggs, beans, dry broad beans, cow's milk, coffee, potatoes, avocados, onions, serrano chiles, guajillo chiles, tomatoes, and green tomatoes. Many of these foods are the major sources of vitamin A, ascorbic acid, and bioavailable iron in the local diet. Most of these foods may be purchased at small community stores (*tiendas*). However, perishable foods, primarily animal products, usually must be purchased either at shops in Temascalcingo or at the weekly markets in both Solís and Temascalcingo. Because only 10% of households possessed a refrigerator, many perishable foods must be eaten soon after purchase. It is often difficult to locate fresh milk, and fresh meat (to a lesser extent) available for purchase locally.

Seasonality of Food Consumption

The high altitude and seasonal pattern of rains creates differences in the availability of some foods during the year. The risk of frost from late October through March means that consumption of locally produced fresh fruits and vegetables is negligible during this period. With warmer weather in the Spring, the consumption of gathered vegetables (*nopales*, *tunas* and *quelites*) resumes. In May through September, the rainy season occurs. At this time, a variety of locally grown fruits and vegetables is available, and consumption of household produce reaches its maximum.

This period of increased availability of locally produced food is associated with decreased cash-flow in many households. The maize harvest occurs in the Fall, after the cessation of the rainy season in September and before the first frosts in November. Prior to the harvest, many households are forced to purchase maize, having consumed the previous harvest (see above). As a result, purchases of some non-maize foods are less frequent during the summer months [4].

Seasonal food availability and differences in household cash flow related to the maize production cycle affect the food intakes of individuals (Chapter Eight). Comparing June-October with November-May, women and men were found to consume approximately 160 and 180 kcal more per day post-harvest period than pre-harvest. Women also consumed more animal products, legumes, *pulque* (a native alcoholic drink), and meat during the post-harvest period. Their intakes of iron, heme iron, and available iron were also higher during these months. A similar pattern of intakes was seen for school-aged children, but not for preschoolers who appeared to eat better during the summer months. This seasonal variation in food intake is relatively minor in comparison to that seen in other areas of the rural Third World. Nevertheless, the pre-season period is associated with a reduction in the intake of micronutrients that are already insufficient to meet biological needs, as will be discussed in Chapter Six.

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Chapter Five.
The Size and Growth of Solís Valley Children

Introduction

The hallmark of marginal malnutrition in developing populations is a high prevalence of small size for age. Despite arguments that small size is not necessarily bad [1], this report shows small size to be a symptom of processes that affect a variety of human functions, including activity, behavior, and cognitive function (see Chapters Fourteen through Seventeen). In this chapter, we describe the general pattern of children's growth and growth-stunting in the study population. In Chapters Twelve and Fourteen, the specific predictors of inter-individual variation in growth and size are described.

The Measurement of Anthropometry

As described in Chapter Two, Mexico CRSP personnel collected weights, lengths, skinfolds, and head circumferences on target infants every month. For target preschoolers and school-aged children, weights were measured monthly, while skinfolds and lengths (preschoolers) and heights (schoolers) were measured every three months. In addition, the anthropometry of all non-target members of the households was measured once.

In this chapter, all Z-scores were calculated using the recently introduced Centers for Disease Control CASP microcomputer program. In other chapters, Z-scores were calculated on the University of Connecticut mainframe computer using a FORTRAN program developed by the Centers for Disease Control in the early 1980s.

The graphs presented in this chapter employ all the cleaned anthropometry data available from target individuals, or from members of target households. In the case of target individuals, each person will have contributed a somewhat varying number of observations. Using a graphical technique developed by Tukey [2], smoothed curves were obtained by dividing the range of x-values (i.e. age) into approximately equally sized groups. The medians and quartiles were then calculated for each age-group. To reduce noise, these were then smoothed using groups of two and three running medians.

The Growth and Size of Infants

Table 5.1 shows the distribution of weights, lengths, and Z-scores for 55 infants with weight measures near birth (0-8 days), 1 month, 3 months, 6 months, and 8 months (plus or minus 14 days). The table shows most infants at birth to be below reference values in length, weight, or weight-for-length. However, over 25% of infants were above the reference on any given measure. By 1 month, over 75% of infants were below reference values for length, and the median dropped from -0.88 to -0.99. The situation for weight improved somewhat in the weeks after birth, the median weight Z-score increasing from -0.46 to -0.22. As might be expected, weight-for-lengths increased from a median of -0.61 to 0.61.

At 3 months, length Z-scores fell slightly from the one month median of -0.99, to -1.09. A similar pattern was seen for weight (a drop from -0.22 to -0.31). Weight-for-length increased due to slower length growth with respect to weight growth.

By 6 months, length Z-scores had fallen considerably since 3 months (from a median of -1.09 to -1.34), as had weight (from -0.31 to -0.78). Again, weight-for-length was normal.

At 8 months, the infants were still falling off against the reference. The median length Z-score was -1.62 and weight Z-score was -1.04. The distributions of weight-for-length are still in the normal range.

Figures 5.1 through 5.9 provide visual representations of the process of stunting. In Figures 5.1 and 5.2, the growth of infants in weight and length is compared with the 50th percentile NCHS [3]. As indicated in Table 5.1, the children fall off in both weight and length with increasing age. This is made clearer in Figures 5.3 and 5.4 where Z-scores are presented. For length, the median (and first and third quartiles) for children within 0-8 days of birth were near but somewhat below NCHS reference values. A sudden drop against the reference is seen shortly after birth; much of this may be an artifact of problems in measuring infants in the first few days after birth, including variability due to water loss. From about 15 days on, the children steadily fall off against NCHS values until nearly 75% are at or below a Z-score of -1.0 at eight months. The graph also suggests that the rate of fall against the NCHS reference increases somewhat at about 3 months of age, and slows near 6 or 7 months.

Figure 5.5 presents length velocity data for these infants as compared to the monthly length velocities of well fed children from the midwest US [4]. The velocities were calculated as the growth rate per day between measures no more than 45 days apart. The midpoint was taken as the measure of 'age.' Each child contributed several different growth velocities. In Figure 5.5, the length velocities of the Mexican children appear to be very close to that of the U.S. children until the age of 120 days when there is a drop in many of the length velocities.

Figure 5.3 shows the weight Z-scores by age. Median weight Z-scores do not fall very much against the reference until approximately 150 days when a steady decline in Z-scores begins.

Table 5.1: Distribution of infant anthropometry (sexes combined).

	N	Mean	SD	Q1	Median	Q3
O-8 days						
Age	55	5.5	3.56	0	8	8
Weight	55	3.2	0.51	3.0	3.2	3.4
Weight Z	55	-0.46	0.94	-1.01	-0.46	0.06
Length	42	49.1	2.17	48.0	49.0	50.2
Length Z	42	-0.80	0.93	-1.36	-0.88	0.06
Wt for Lgth Z	21	-0.30	1.07	-0.83	-0.61	0.47
1 month						
Age	55	30.8	4.60	28	31	33
Weight	55	4.0	0.59	3.5	4.0	4.4
Weight Z	55	-0.20	0.82	-0.79	-0.22	0.43
Length	52	51.9	2.22	50.3	52.1	53.6
Length Z	52	-0.95	0.87	-1.40	-0.99	-0.23
Wt for Lgth Z	47	0.58	0.87	0.19	0.61	1.08
3 months						
Age	55	92.4	7.25	90	92	94
Weight	55	5.5	0.74	5.0	5.5	6.0
Weight Z	55	-0.26	0.83	-0.71	-0.31	0.29
Length	55	57.7	2.54	55.8	57.3	59.6
Length Z	55	-1.12	0.87	-1.7	-1.09	-0.48
Wt for Lgth Z	55	0.79	0.86	0.22	0.70	1.3
6 months						
Age	55	183.7	9.22	180	183	189
Weight	55	6.9	1.02	6.2	6.9	7.6
Weight Z	55	-0.77	1.03	-1.42	-0.78	0.00
Length	55	63.3	2.74	61.3	63.0	65.8
Length Z	55	-1.38	0.90	-2.07	-1.34	-0.69
Wt for Lgth Z	55	0.43	1.03	-0.34	0.44	1.14
8 months						
Age	55	239.5	9.92	230	241	246
Weight	55	7.4	1.05	6.6	7.5	8.3
Weight Z	55	-1.14	1.01	-1.81	-1.04	-0.39
Length	55	65.8	2.9	63.6	65.7	69.0
Length Z	55	-1.54	0.94	-2.18	-1.62	-0.96
Wt for Lgth Z	55	0.10	0.90	-0.54	0.05	0.66

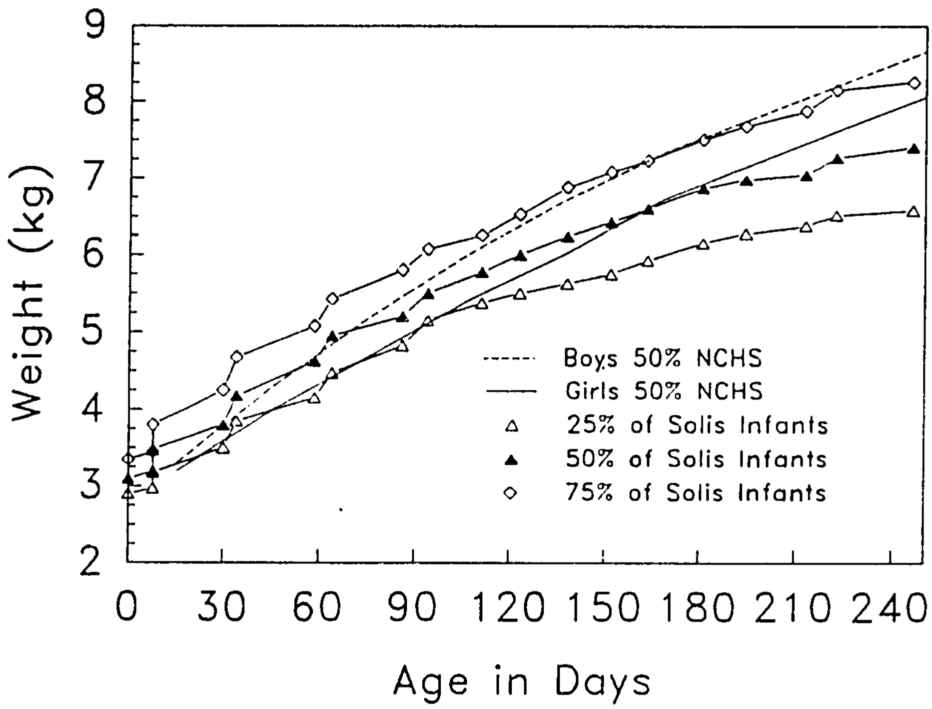

Figure 5.1: Changes in infant weight with age in comparison to 50% NCHS girls and boys.

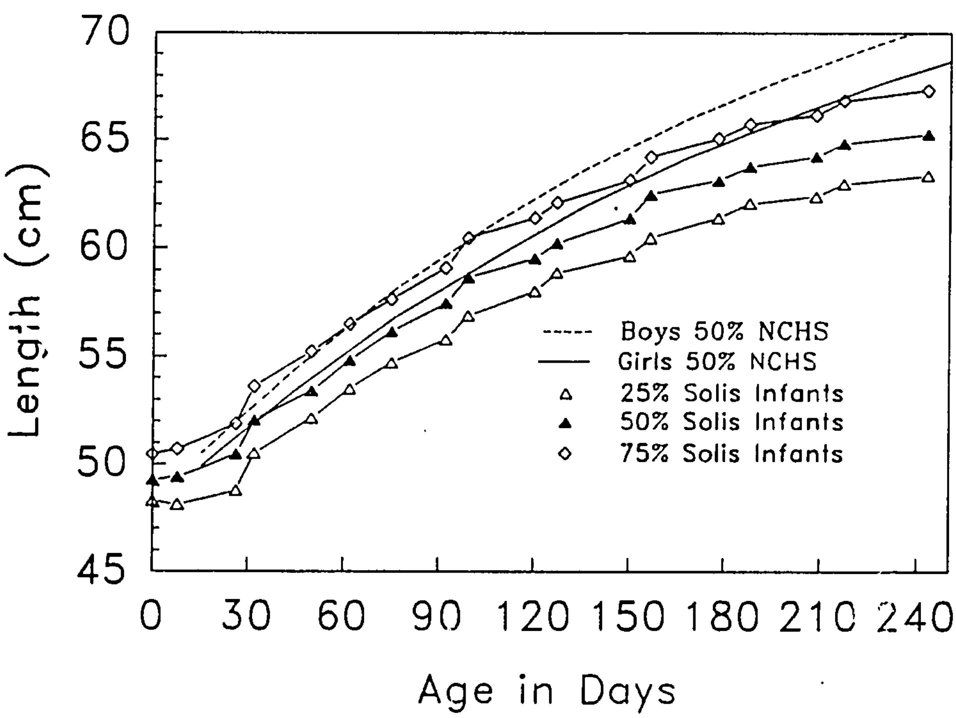

Figure 5.2: Growth in infant's length with age in comparison to 50% NCHS for girls and boys.

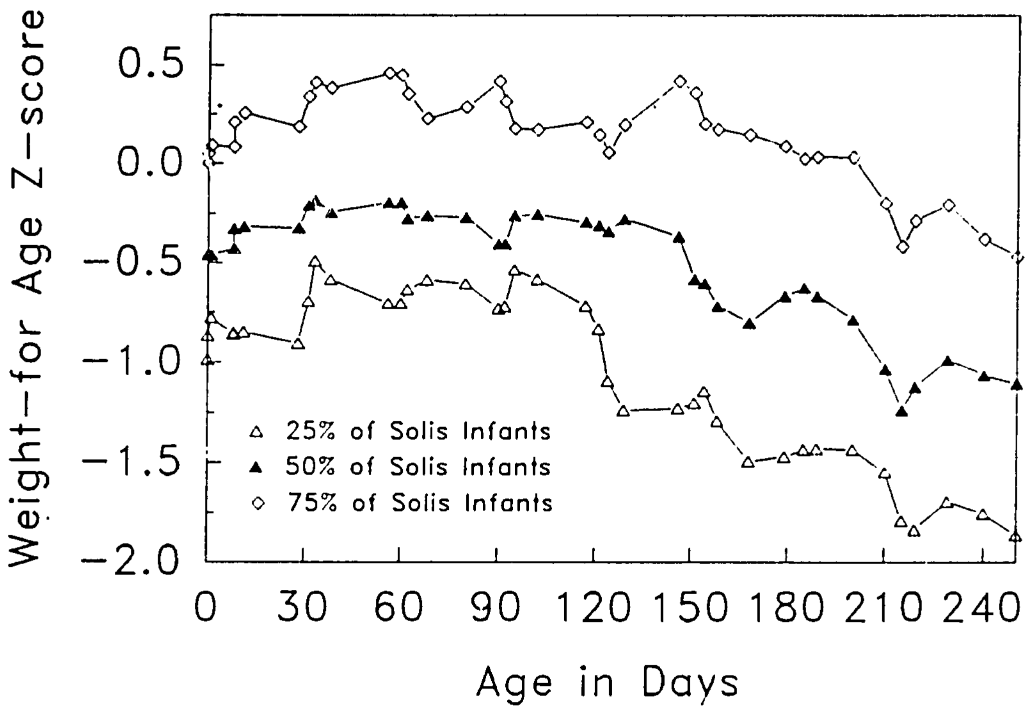

Figure 5.3: Change in infant weight Z-scores with age.

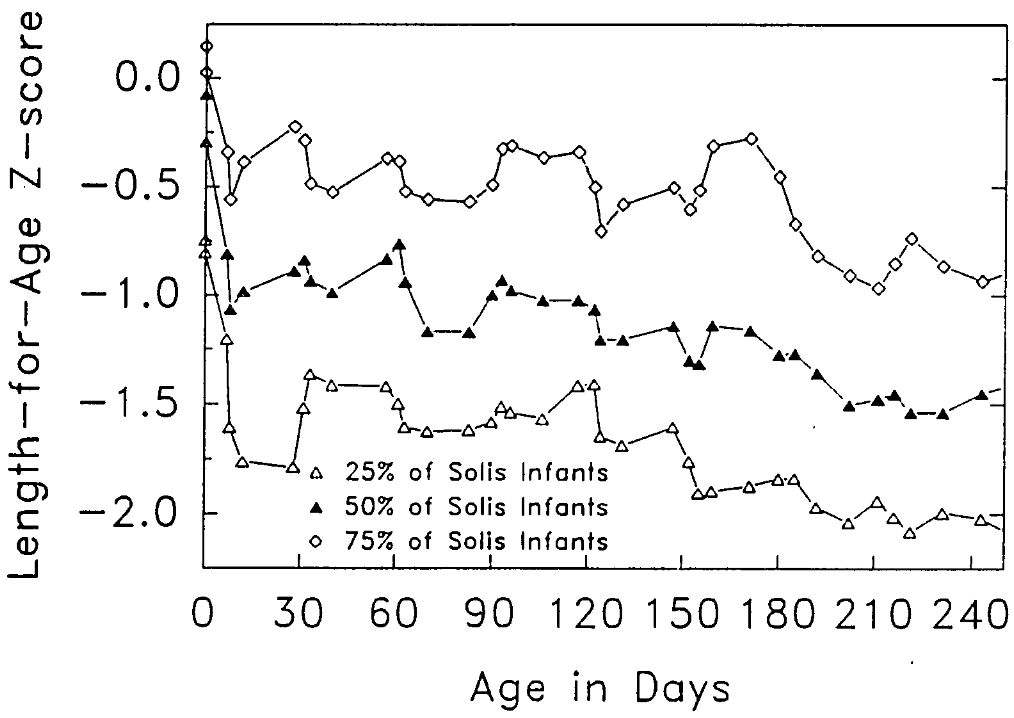

Figure 5.4: Change in infant length Z-scores with age.

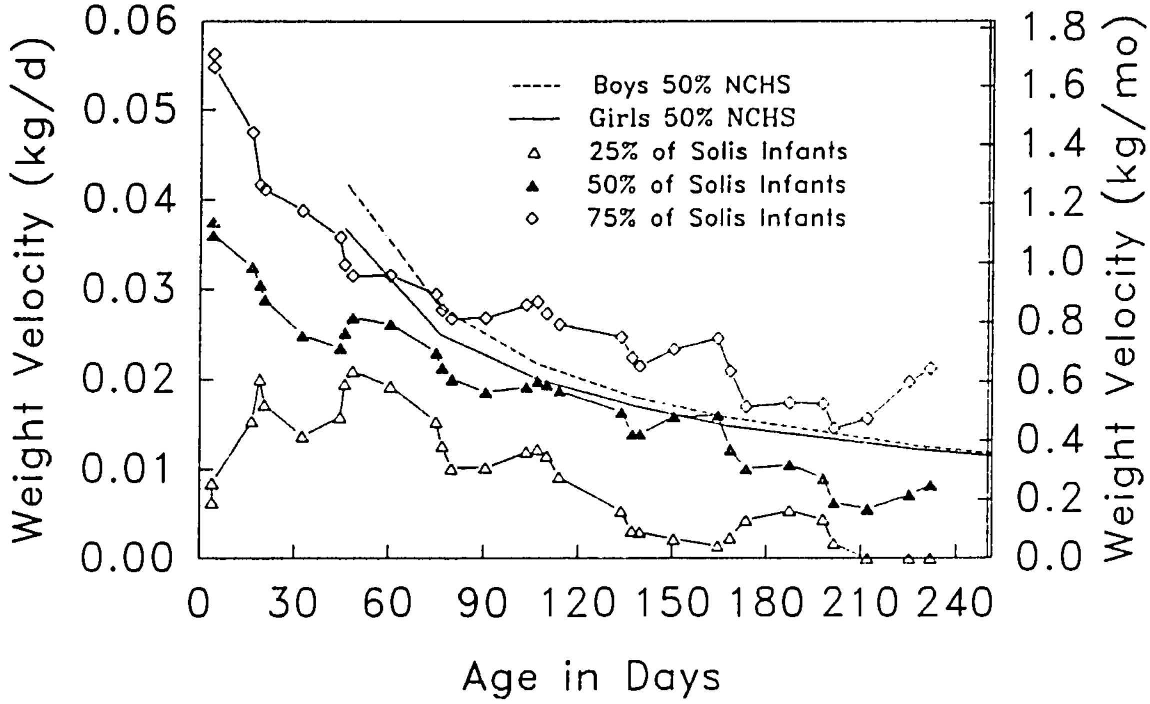

Figure 5.5: Change in infant weight growth velocity (kg/d) with age and in comparison to healthy U.S. infants.

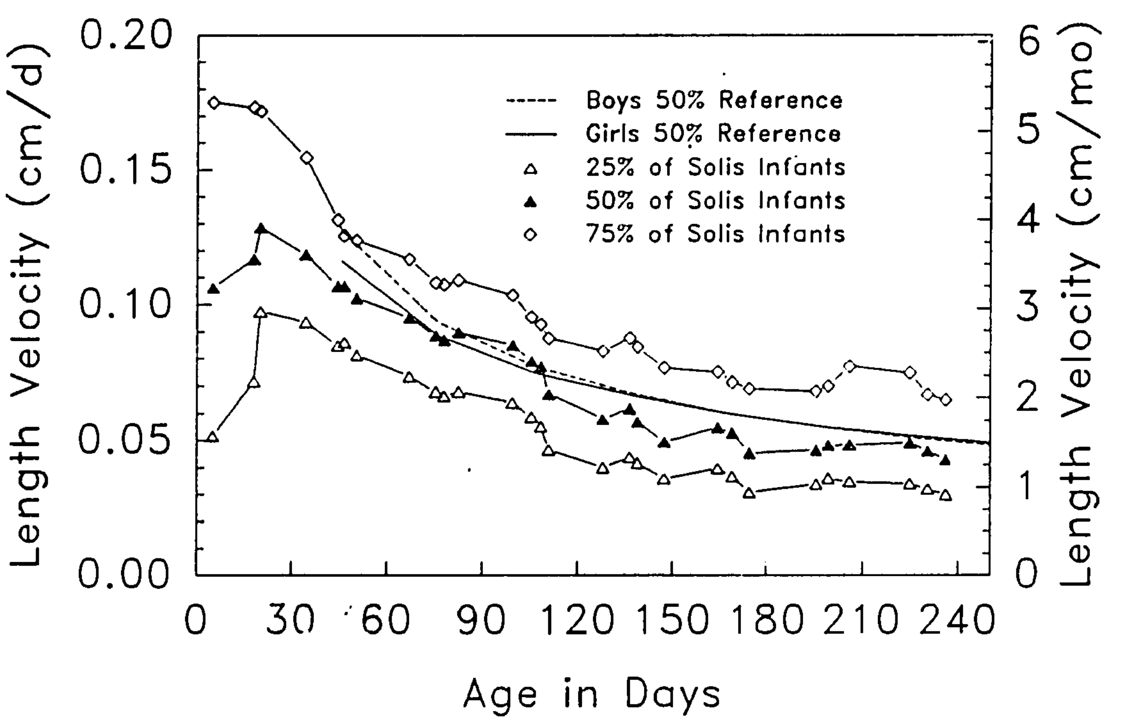

Figure 5.6: Change in infant length growth velocity (cm/d) with age and in comparison to healthy U.S. infants.

Table 5.2: Correlations among infant weight and length at different ages.

	1 mo	3 mo	6 mo	8 mo
Weight (N=55)				
0-8 Days	0.58	0.42	0.31	0.36
1 Month	--	0.75	0.58	0.57
3 Months	--	--	0.80	0.76
6 Months	--	--	--	0.84
Length				
0-8 Days	0.56[1]	0.61[2]	0.56[2]	0.57[2]
1 Month	--	0.78[3]	0.64[3]	0.60[3]
3 Months	--	--	0.87[4]	0.82[4]
6 Months	--	--	--	0.92[4]

[1] N=39 [2] N=42 [3] N=52 [4] N=55

The weight growth velocities drop at about 165 days (although in some children this occurs earlier) (Figure 5.5).

Figures 5.1 - 5.6 show important population-level trends in growth but fail to demonstrate the strong tracking in size that occurs in these children. Table 5.2 gives the Pearson correlations among the weight and length measures for different periods of time. Length at 0-8 days was a very good predictor of weight at 8 months ($r=0.57$ or R-square=0.34), while weight at 0-8 days was a weaker predictor of weight at 8 months ($r=0.36$, R-square=0.13). At 1 month, the correlation of length with length at 8 months was stronger ($r=0.60$, R-square=0.36), as was that for weight at 1 month with weight at 8 months ($r=0.57$, R-square=0.34). As would be expected, the correlations become stronger as the time between measures becomes shorter.

Figure 5.7 shows the scatterplots for length and weight at 0-8 days and 3 months vs weight or length at 8 months. As indicated by the correlations, the associations at 1 and 3 months are very good predictors of size at 8 months, showing the short children at 1 month to be short at 8 months. In fact, regression models show length at 1 month to predict length at 8 months to within approximately 2.5 cm for 90% of the infants, and weight at 1 month to predict weight at 8 months within approximately 1 kg.

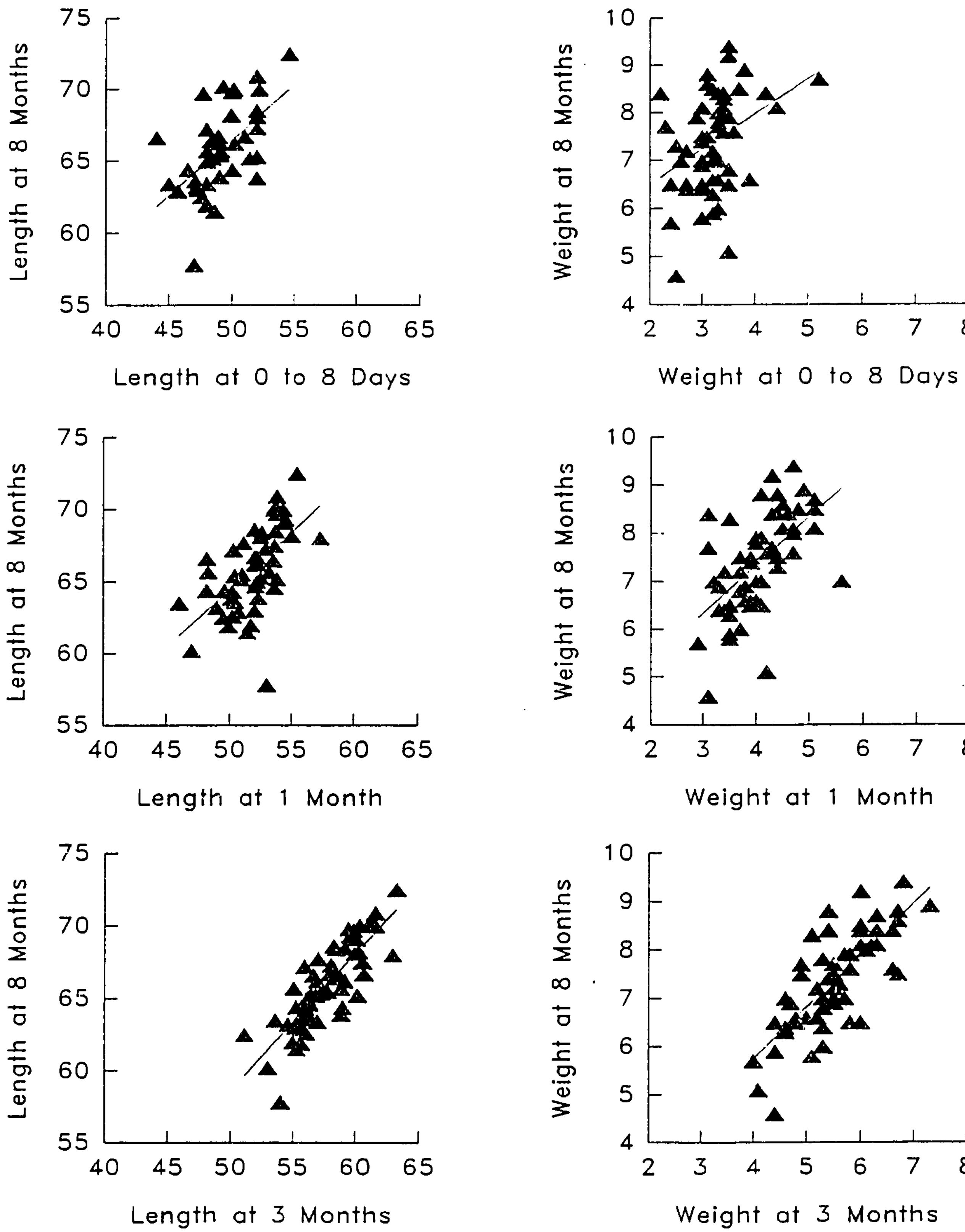

Figure 5.7: The relationship of size at birth, one, and three months to size at eight months.

Growth and Size of Preschoolers: 18 to 30 Months

By the time children from the target communities reach 18 months, they have fallen off still more against NCHS reference values (Table 5.3). At 8 months, the median Z-scores for infants were -1.04 for weight and -1.62 for length. In comparison, the median Z-scores for 30 preschoolers with measures within two weeks of 18 months were -1.60 for weight and -2.30 for length. At 18 months, the average child was 7 cm shorter and 2 kilograms lighter than the 50th percentile NCHS for boys. As seen for infants, however, the weight-for-length Z-scores were slightly below the reference values, but not so much as for either weight or length.

Table 5.3 presents weights and lengths at 22, 26, and 30 months for 47 preschoolers with data at each age. Because lengths were measured every three months, some lengths were interpolated. For this sample, the 22 month figures for weight are very similar to those seen for the 18 month sample. Moreover, the weight Z-scores for the same children at 22, 26, and 30 months are very similar. However, the situation for length is very different. For the 30 children at 18 months, the median length Z-score was -2.30. In contrast, the Z-scores for the 47 preschoolers were much worse at 22 months, the median Z-score being -2.50, and 25% of children having length Z-scores below -3.13! At 26 months, however, the length Z-scores for these children had improved considerably, the median Z-score being -1.91 and the first quartile being -2.55. At 30 months, the length Z-scores had improved still more, the median rising to -1.74.

Table 5.3 suggests a period of catch-up in length growth beginning sometime after 18 months and continuing through 30 months. Figure 5.9 shows lengths of all preschoolers by age, and the acceleration in length growth at approximately 20 months. Figure 5.11 confirms this observation, length Z-scores falling until age 20 or 21 months when length Z-scores begin a steady increase against NCHS values. Weight Z-scores are remarkably stable during this year (Figure 5.10).

Table 5.4 presents the Pearson correlations among weight and length at 18, 22, 26, and 30 months. As seen for infants, prior size is a very good predictor of subsequent size. In fact, prior size for preschoolers is an even better predictor of subsequent size than it is for infants: length at 22 months explains 81% (r=0.90) of variation in length eight months later, while weight at 22 months explains 56% (r=0.75) of variation in weight at 30 months.

The Growth of Non-Target Children: 2.5 to 7 years

The Mexico CRSP collected anthropometry once on all persons in the household. Of these, 218 people were aged 2.5 to 7 years. Figure 5.12 shows little apparent change in weight Z-score for these children. However, Figure 5.13 shows signs of improving height Z-scores with age. This would appear to be an extension of the improving trend in height that begins at 20 months

Table 5.3: Distribution of preschooler anthropometry (sexes combined).

	N	Mean	SD	Q1	Median	Q3
18 months						
Age	30	18.1	0.31	17.9	18.2	18.4
Weight	30	9.5	1.23	8.9	9.5	10.2
Weight Z	30	-1.50	1.10	-2.10	-1.60	-0.64
Length	30	74.9	3.80	73.5	74.9	76.6
Length Z	30	-2.30	1.31	-2.78	-2.30	-1.48
Wt for Lgth Z	30	-0.50	0.60	-0.90	-0.58	-0.11
22 months						
Age	47	21.9	0.30	21.6	21.8	22.1
Weight	47	10.2	1.17	9.2	10.2	10.7
Weight Z	47	-1.28	1.07	-2.16	-1.36	-0.61
Length	47	77.5	3.44	75.8	77.0	79.8
Length Z	47	-2.36	1.09	-3.13	-2.50	-1.48
Wt for Lgth Z	47	-0.20	0.78	-0.73	-0.41	0.20
26 months						
Age	47	26.0	0.30	25.8	26.0	26.3
Weight	47	11.0	1.28	10.1	10.9	11.9
Weight Z	47	-1.25	1.06	-1.88	-1.43	-0.73
Length	47	80.6	3.63	78.3	80.8	82.7
Length Z	47	-1.89	1.11	-2.55	-1.91	-1.24
Wt for Lgth Z	47	-0.24	0.69	-0.72	-0.32	0.19
30 months						
Age	47	30.0	0.33	29.7	20.0	30.4
Weight	47	11.7	1.16	11.0	11.6	12.4
Weight Z	47	-1.17	0.87	-1.71	-1.20	-0.63
Length	47	83.8	3.74	80.8	83.8	86.2
Length Z	47	-1.75	1.08	-2.59	-1.74	-1.06
Wt for Lgth Z	47	-0.28	0.59	-0.64	-0.26	0.07

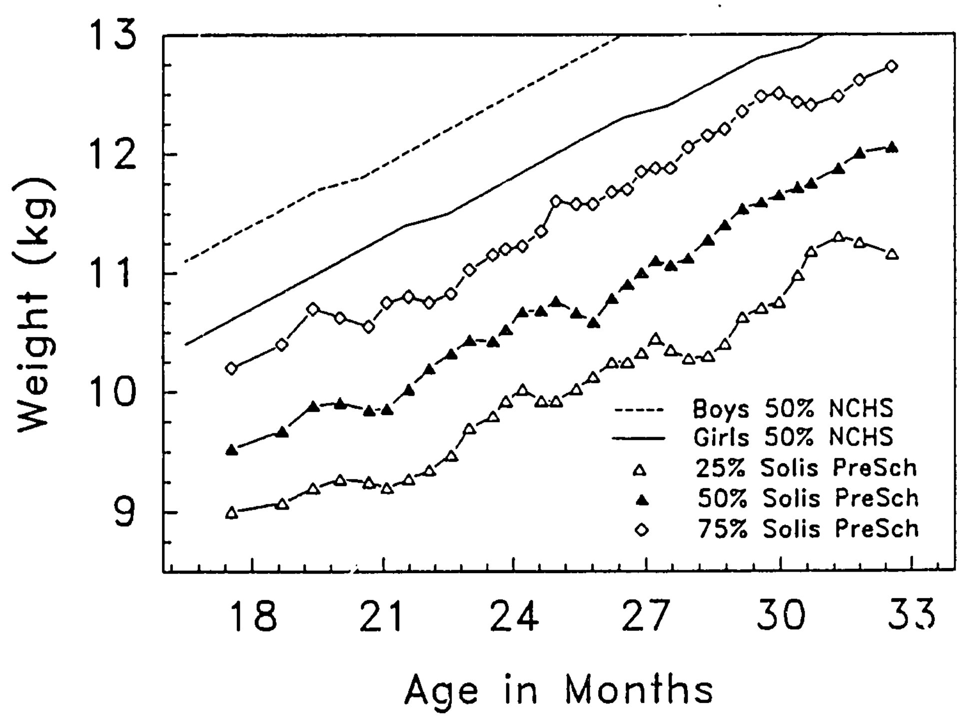

Figure 5.8: Change in preschooler weight with age in comparison to 50% NCHS girls and boys.

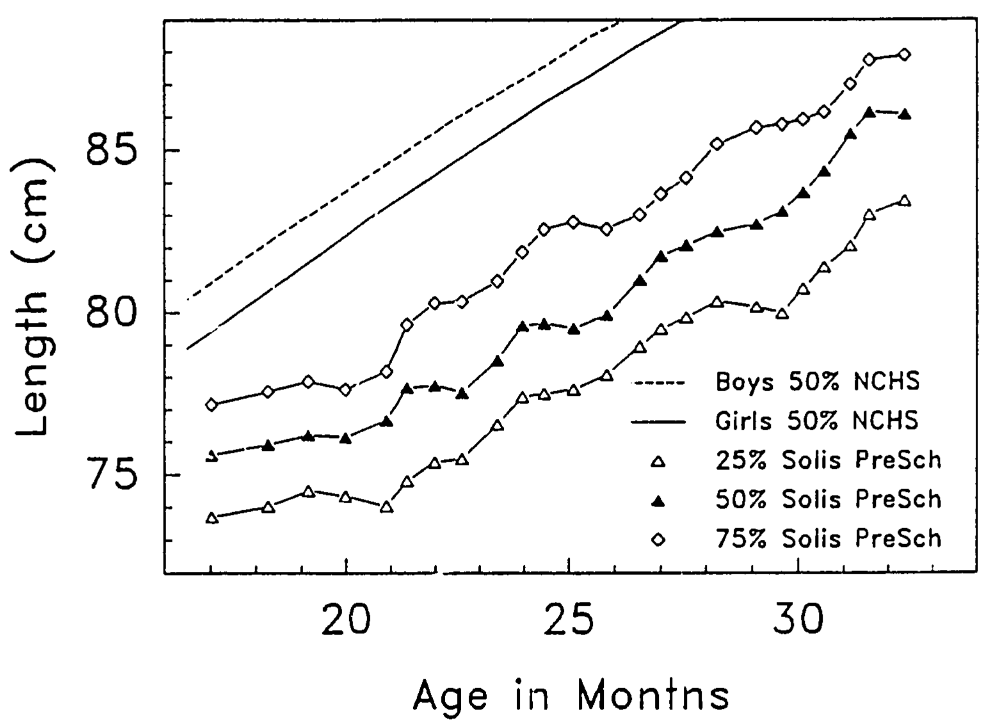

Figure 5.9: Change in preschooler length with age in comparison to 50% NCHS girls and boys.

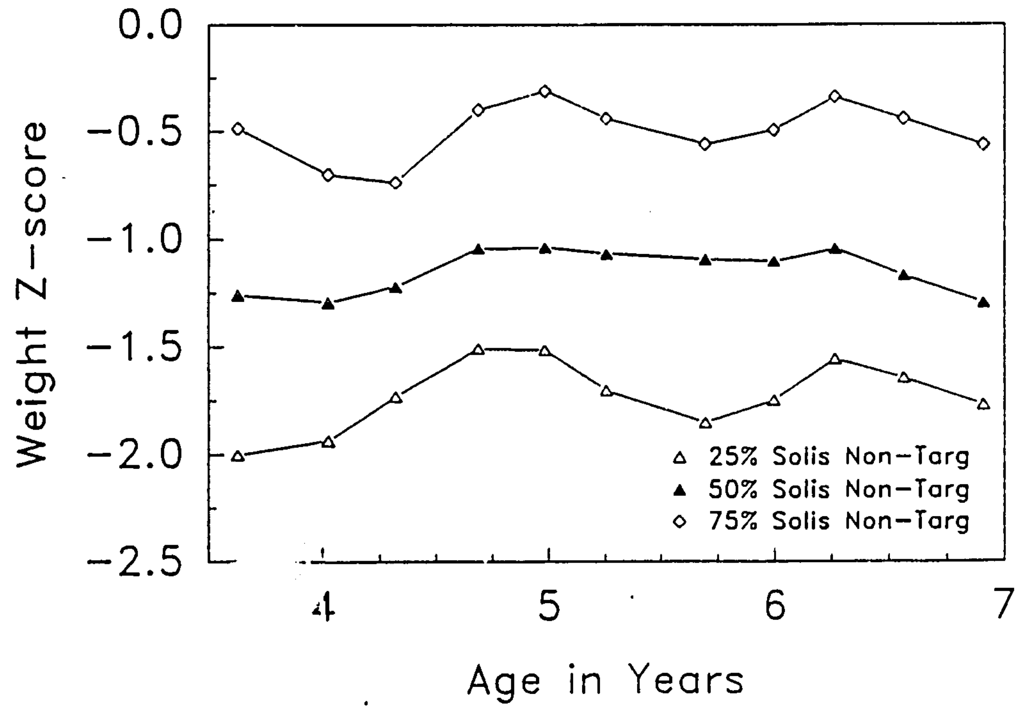

Figure 5.12: Change in weight Z-scores with age for non-target children aged 2.5 to 7 years.

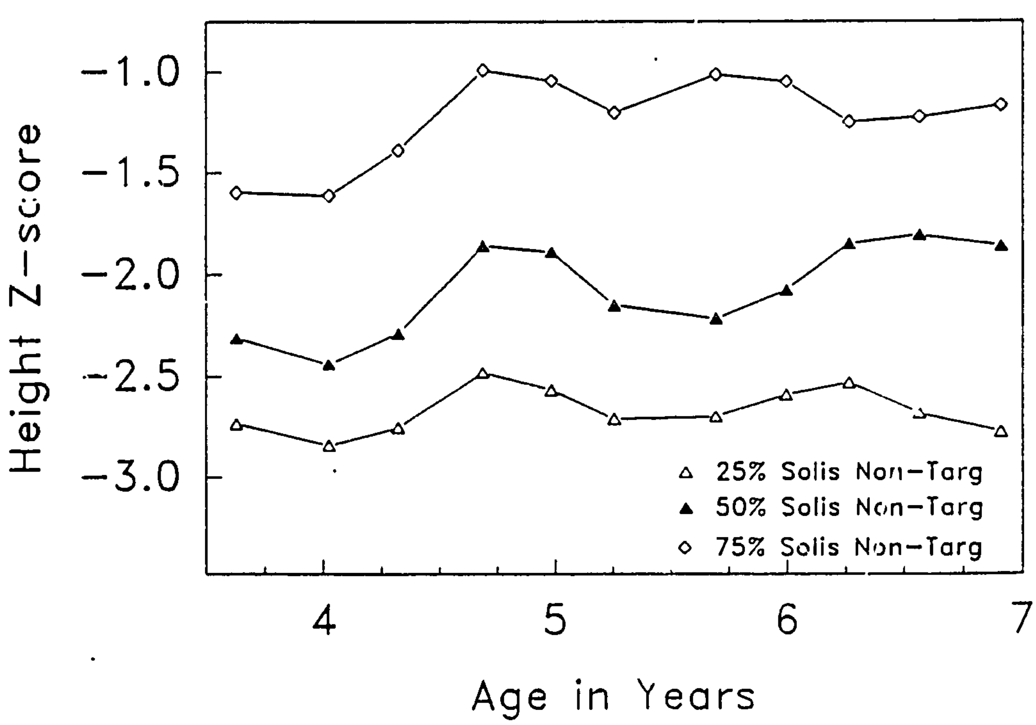

Figure 5.13: Change in length Z-scores with age for non-target children aged 2.5 to 7 years.

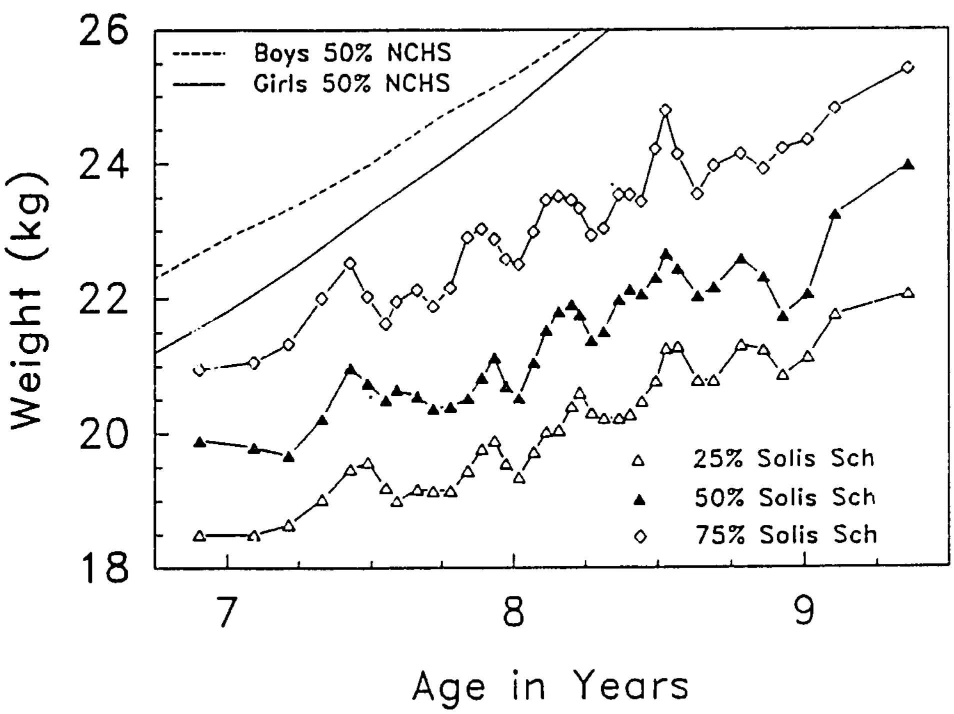

Figure 5.14: Change in school-aged children's weight with age in comparison to 50% NCHS girls and boys.

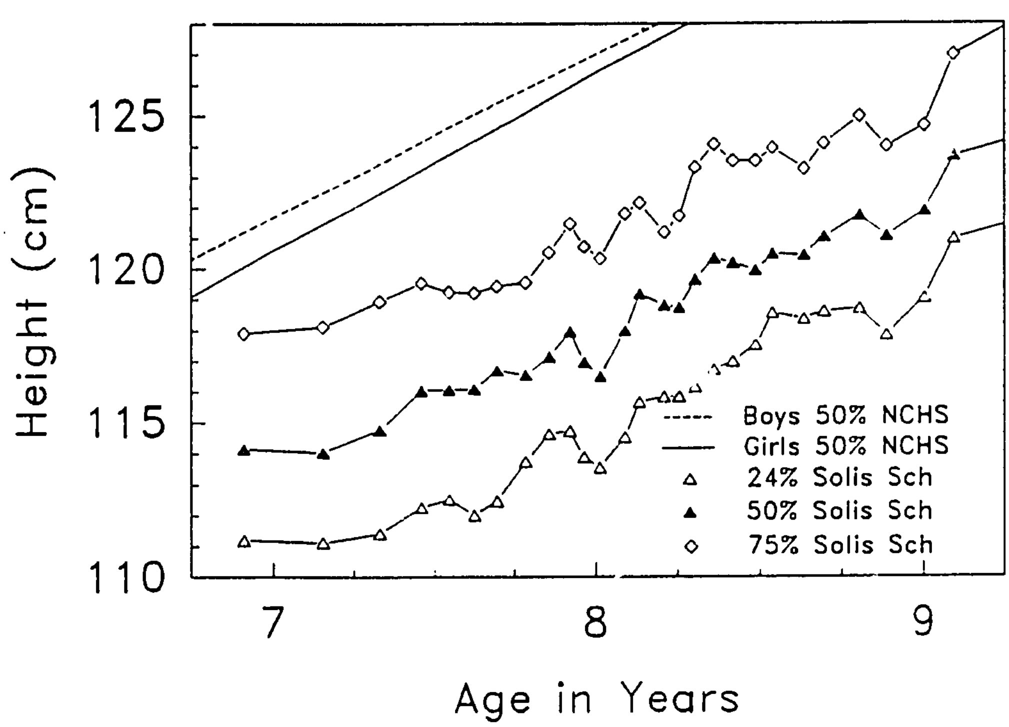

Figure 5.15: Change in school-aged children's length with age in comparison to 50% NCHS girls and boys.

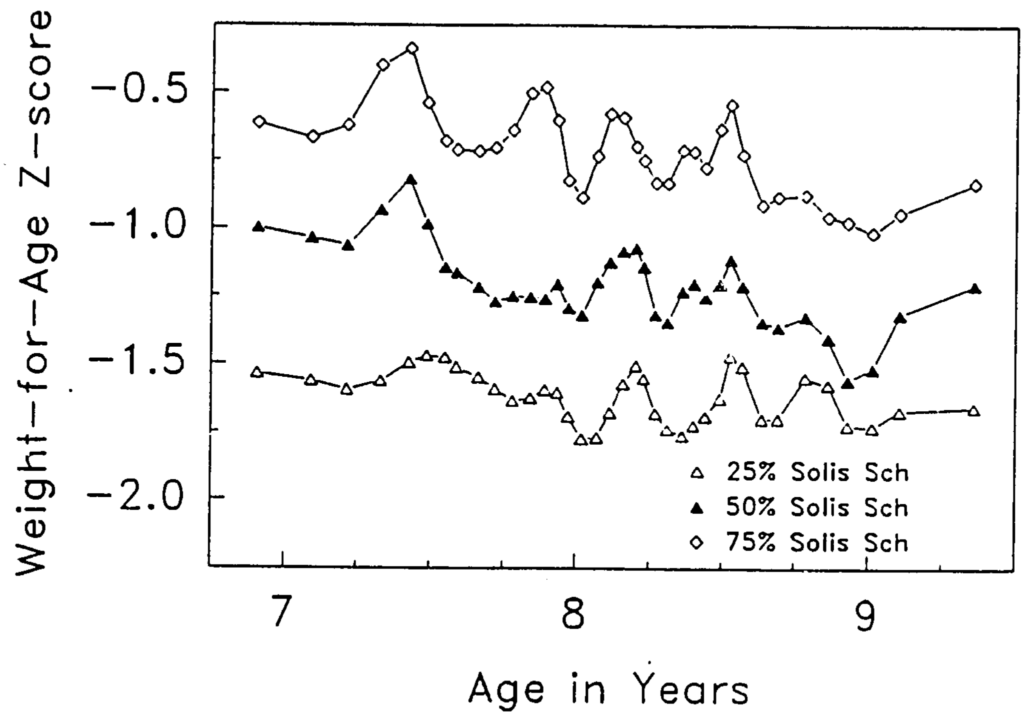

Figure 5.16: Change in school-aged children's weight Z-scores with age.

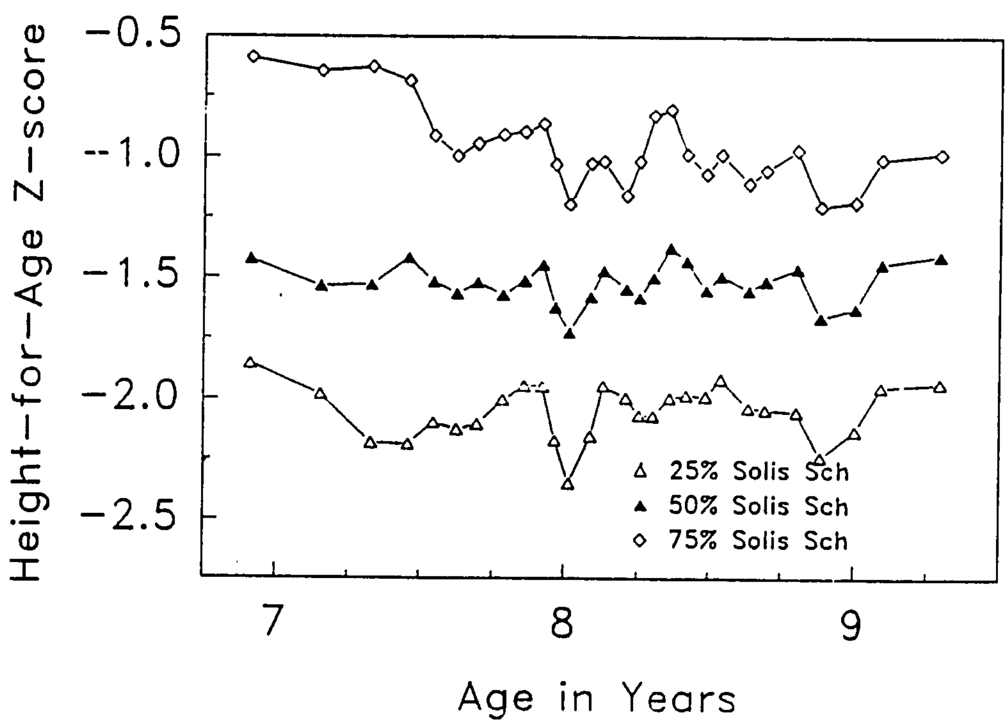

Figure 5.17: Change in school-aged children's height Z-score with age.

Table 5.5: Distribution of schooler anthropometry at 8 years of age (sexes combined).

	N	Mean	SD	Q1	Median	Q3
Age	73	7.99	0.05	7.96	7.98	8.03
Weight	73	21.2	2.75	19.4	20.9	23.1
Weight Z	73	-1.20	0.79	-1.78	-1.35	-0.70
Length	73	117.5	5.44	113.5	117.2	120.3
Length Z	73	-1.61	0.96	-2.16	-1.16	-1.18
Wt for Lgth Z	73	-0.11	0.78	-0.66	-0.14	0.22

When Does Stunting Occur?

Taken together, the plots and descriptive statistics presented in this chapter suggest that most of the stunting in these children occurs between birth and 20 months. Though the infants tended to be small at birth, they were not far from NCHS reference values for age given the small size of their mothers. The growth velocity data for the infants, and to some extent the Z-scores, suggest that the serious drop in size against NCHS values occurs sometime after 3 months of age. This drop appeared to occur for nearly all children, and continued at least until 8 months. The preschooler data suggest that this fall against the international reference continues until the age of approximately 20 months, when 25% of preschoolers had fallen below a -3.13 Z-score for length. At this time, the children begin to slowly improve in length, a population trend that continued for several years. By 7 to 9 years, school-aged children were very similar to preschoolers in weight, and much better in terms of length.

The timing of these results raises the question as to what causes the growth stunting at 4 months and its apparent reversal at 20 months. As many children receive their first supplementary foods in reasonable quantities starting at about 3 months (see Chapter Ten), infant supplementation is a potential candidate for explaining the growth stunting observed in these children. Or, does infant growth begin faltering as a result of the exhaustion of stores gained during pregnancy combined with poor milk quality or an insufficient milk supply? Is the apparent catch-up of preschoolers in length after 20 months due to some change in their diet? Many children are weaned of the breast at this age, and the median birth interval is approximately 20 months. Perhaps children this age stop eating 'baby' foods and begin to eat a child's diet.

Two observations in this chapter are also of potentially great importance:

- **growth faltering occurs in all, or most, segments of this population.** If variation in weight and length increased steadily with age, and one segment stayed close to the

NCHS values, then one could conclude that some children were not exposed to those factors that creating stunting in the Solís Valley. As this is not the case, it follows that nearly all children in the study population were exposed to some situation(s) that negatively affected growth. This limits to some degree the ability of this study to identify those factors causing stunting, because the full range of exposure to the harmful situations is not represented.

- **small children at 1 and 3 months are *very* likely to be small at 8 months.** The regressions show very little deviation of actual from predicted size at 8 months. This suggests two possibilities: a) most variation in infant size is due to processes that affect the infant at a point prior to 4 months of age (either during pregnancy or early lactation), or b) most variation in infant size is due to on-going processes (such as household food supply) that have a continuing effect on infant growth via effects on the mother and/or infant. Both hypotheses are plausible and point to the importance of very early nutrition as a determinant of later child growth and development.

References

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4. Roche AF, Himes JH. Incremental growth charts. Am J Clin Nutr 1980;33:2041-2052.

Chapter Six.
Nutrient Intake, Bioavailability and Food Patterns

This chapter describes the foods and nutrients consumed by target individuals. The sources of dietary energy are identified, as is the intake and adequacy of specific nutrients. Because of the high intake of plant-source foods and the potentially adverse effects of their phytate and fiber content on mineral bioavailability, these issues are discussed by exploring how dietary quality (relative dependence on animal versus plant products) predicts children's attained size.

Sources of Dietary Energy

Calculating the percent of dietary energy obtained from specific foods provides a picture of the dietary pattern in the Solís Valley (Tables 6.1 to 6.3). By far the most striking aspect of the diets is the importance of plant products in general, and of *tortillas* in particular. The consumption of animal products is very low in all age groups, compared, for example, with the United States population where 60% of the energy intake is derived from this source.

A description of the supplemental foods fed to infants can be found in Chapter Twelve. In the first few months after birth, supplementation is low and consists mainly of sugar and milk. Between four and eight months there is an increase in cereals provided, mostly in the form of a ground rice or corn beverage called *atole.*

Animal products supply slightly more energy in the diet of preschoolers compared to schoolers (Table 6.1). This is due predominantly to preschooler's higher median intake of dairy products (which nevertheless only amounts to 20 ml milk per day) and to a lesser extent eggs (one eighth of an egg per day), while meat intake (median one quarter ounce per day) is similar at both ages. Preschoolers also obtain a slightly lower percent of their energy from *tortillas,* and more from the "other plants" category which includes bread, pasta, rice, root crops, oil, candies and non-dairy beverages none of which contributes more than 7% to total energy intake on average.

All groups of adults (men, non-pregnant/non-lactating women [NPNL], pregnant women and lactating women) have very similar dietary patterns. This is perhaps not surprising as the food pattern of individuals in these communities is primarily dependent on their household dietary pattern and there is relatively little food eaten outside the home. Nevertheless, these results do not indicate favoritism toward men in, for example, animal product consumption. The main difference between the diets of men and women is the higher intake of *pulque* by men. *Pulque* contains about 420 kcal/liter so that the median intake by men is about 780 ml/day, while 25% consume at least 1.5 liters daily. Women drink about half these amounts. The dietary pattern is

Table 6.1: Distribution of children's percent of energy from different foods.

PRESCHOOLERS (N= 87)

	Mean	SD	Q1	Median	Q3
% Animal Products	11.7	8.82	5.4	9.1	14.4
% Meat	3.0	2.36	1.5	2.5	3.4
% Eggs	3.0	2.84	1.2	2.7	3.6
% Dairy	4.9	6.50	0.6	2.4	7.3
% Plant Products	88.3	8.82	85.6	90.9	94.6
% *Tortillas*	50.7	16.49	40.7	51.4	62.8
% Legumes	5.7	3.46	3.3	4.9	7.7
% Vegetables	1.2	0.59	0.8	1.1	1.6
% Fruit	0.6	1.23	0.0	0.2	0.6
% *Pulque*	0.9	2.66	0.0	0.0	0.3
% Other Plant	29.2	11.49	18.9	28.5	38.2

SCHOOL-AGED CHILDREN (N=110)

	Mean	SD	Q1	Median	Q3
% Animal Products	7.1	5.29	3.4	5.8	8.5
% Meat	2.6	2.02	1.1	2.0	3.8
% Eggs	1.8	1.22	0.9	1.6	2.5
% Dairy	2.2	3.73	0.0	0.6	2.9
% Plant Products	92.9	5.29	91.5	94.2	96.6
% *Tortillas*	64.7	13.86	58.6	65.7	73.6
% Legumes	5.2	3.11	2.8	4.6	6.8
% Vegetables	1.3	0.66	0.8	1.2	1.5
% Fruit	0.3	0.86	0.0	0.0	0.2
% *Pulque*	1.0	2.44	0.0	0.0	0.9
% Other Plant	20.5	10.31	12.9	20.0	25.3

also unaffected by pregnancy or lactation, although food intake does increase late in pregnancy and throughout lactation (Table 6.3 and Chapter Eleven).

Only about 5% of dietary energy for adults comes from animal sources and tends to be equally provided by meat, eggs and dairy products. To give an idea of the low amounts consumed, for NPNL women the median amounts are equivalent to approximately half an ounce (14 g) of cooked beef, a quarter of an egg and less than a tenth of a cup of milk (40 ml) per day. The

Table 6.2: Distribution of men's and non-pregnant/non-lactating women's percent of energy from different foods.

MEN (N= 148)

	Mean	SD	Q1	Median	Q3
% Animal Products	6.5	5.58	3.5	4.9	8.0
% Meat	2.8	2.40	1.2	2.2	3.6
% Eggs	1.4	1.08	0.7	1.2	1.8
% Dairy	1.7	3.60	0.0	0.3	2.0
% Plant Products	93.5	5.58	92.0	95.1	96.5
% *Tortillas*	59.0	12.34	50.7	58.5	68.2
% Legumes	4.7	2.75	2.6	4.5	5.8
% Vegetables	1.2	0.69	0.8	1.1	1.4
% Fruit	0.2	0.79	0.0	0.0	0.1
% *Pulque*	12.7	11.44	1.4	11.1	21.5
% Other Plant	15.7	9.57	8.3	13.8	20.1

NON-PREGNANT/NON-LACTATING (N=103)

	Mean	SD	Q1	Median	Q3
% Animal Products	6.9	5.80	3.1	5.5	8.5
% Meat	2.9	2.34	1.1	2.4	4.1
% Eggs	1.3	1.24	0.4	1.1	1.7
% Dairy	2.2	3.67	0.0	0.6	2.8
% Plant Products	93.1	5.80	91.5	94.5	96.9
% *Tortillas*	60.5	13.02	51.8	61.1	69.4
% Legumes	5.3	4.03	2.7	4.6	7.1
% Vegetables	1.2	0.62	0.8	1.2	1.6
% Fruit	0.3	0.80	0.0	0.0	0.2
% *Pulque*	6.4	7.92	0.0	3.4	10.4
% Other Plant	19.4	9.75	12.5	18.4	23.9

Table 6.3: Distribution of pregnant and lactating women's percent of energy from different foods.

	PREGNANT (N= 96)				
	Mean	SD	Q1	Median	Q3
% Animal Products	6.5	4.22	3.8	5.2	8.5
% Meat	2.8	2.37	1.2	2.1	3.8
% Eggs	1.6	1.39	0.5	1.2	2.3
% Dairy	1.8	3.00	0.0	0.5	2.5
% Plant Products	93.5	4.22	91.5	94.8	96.2
% *Tortillas*	64.3	10.53	57.2	65.0	71.5
% Legumes	4.9	3.52	2.4	4.0	6.3
% Vegetables	1.2	0.68	0.7	1.1	1.6
% Fruit	0.2	0.48	0.0	0.0	0.1
% *Pulque*	4.6	6.12	0.0	1.2	7.1
% Other Plant	22.9	8.69	16.5	23.2	28.7

	LACTATING (N= 154)				
	Mean	SD	Q1	Median	Q3
% Animal Products	6.3	5.20	3.0	4.9	7.7
% Meat	2.5	2.07	1.0	2.0	3.2
% Eggs	1.5	1.13	0.7	1.4	2.2
% Dairy	1.9	3.86	0.0	0.3	1.8
% Plant Products	93.7	5.20	92.3	95.1	97.0
% *Tortillas*	64.2	11.72	58.3	65.9	73.0
% Legumes	4.9	3.08	2.9	4.5	6.4
% Vegetables	1.1	0.61	0.6	1.0	1.4
% Fruit	0.1	0.44	0.0	0.0	0.1
% *Pulque*	5.4	6.62	0.0	2.2	9.1
% Other Plant	18.0	9.13	11.6	16.4	23.4

potential significance of the fact that by far the majority of dietary energy is supplied as *tortillas*, as well as by ***pulque*** for adults, is that the quality of the diets is expected to be poor. That is, mineral absorption from such diets is likely to be very low and the intake of some vitamins (e.g. vitamins A and B_{12}) will probably be inadequate.

Adequacy of Intake of Specific Nutrients

The intake of specific nutrients by preschoolers and schoolers is described in Table 6.4, for men and NPNL women in Table 6.5, and for pregnant and lactating women in Table 6.6. Units are kcal for energy, grams for protein and fat, μg for pantothenic acid, folate and vitamin B_{12}, niacin equivalents for niacin, μg equivalents for retinol, and mg for the remainder.

In order to judge the adequacy of nutrient intake, these values are compared to the FAO/WHO/-UNU recommendations for energy and protein [1], and the 1989 US Recommended Dietary Allowances for other nutrients [2], in Tables 6.7 to 6.9. Several factors were taken into consideration when calculating the energy and protein intakes; these are described as follows referring to relevant pages in the FAO/WHO/UNU report. For energy, the recommended intakes were calculated to be 103 kcal/kg (p. 95) times 10.6 kg (median weight at 24 months) for preschoolers, and 79.5 kcal/kg (p. 95) times 21.3 kg (median weight during the study) for schoolers. For protein, recommendations were taken to be 1.15 g/kg (reference protein, p. 105) times 0.82 (digestibility correction for maize and bean diet, p. 109) for preschoolers, and similarly 1.01 g/kg times 0.82 for schoolers. No correction was used for the amino acid score of the diets although this would have raised the recommended intakes by about 30% (using an amino acid score of 62% for a maize/bean Guatemalan diet, p. 124); to use this correction may have underestimated the actual amino acid score because the children do consume some wheat and rice. Beaton et al. [3] have estimated a zero probability of inadequate protein intakes in these children.

For adult men BMR was calculated to be (11.6 x 66 kg actual body weight + 879, the WHO equation for men age 30-60 years, p.71) = 1645 kcal/day, times 1.78 (estimated activity factor for a subsistence farmer, p. 77) for a total of 2927 kcal/day. For women BMR was (14.7 x 60.8 kg actual weight + 496, the WHO estimate for women age 18-30 years, p. 71) = 1390 kcal/day, times 1.76 (estimated activity factor for a rural woman in a developing country, p. 78) for a total of 2446 kcal/day. The mean weight of the pregnant sample during the first trimester is 53.5 kg (i.e. less than for NPNL women), with an additional 285 kcal/day requirement (p. 85), so that recommended intakes would be 2542 kcal/day. In lactation women weighed 57.5 kg at 3-6 months post-partum, and would need an additional 500 kcal/day for milk production (p. 89), so that the recommended intake would be 2861 kcal/day. The estimates for pregnant and lactating women assume no decrease in activity level, which, based on cultural practices and some evidence from activity recalls [4] is probably not the case at least in early lactation. For recommended adult protein intakes we used a value of 0.75 g/kg reference protein (p. 82) times 0.82 to correct for digestibility in the predominantly maize and beans diet. Estimated recommended intakes were 60 g/day for adult men, 56 g/day for NPNL women, 62 g/day in

Table 6.4: Distributions of children's intakes of selected nutrients.

	PRESCHOOLERS (N= 87)				
	Mean	SD	Q1	Median	Q3
Energy	1086	270.2	898	1052	1242
Protein	32.5	7.88	26.7	32.5	37.9
Fat	27.1	8.33	21.1	25.7	32.8
Calcium	496	142.3	399	484	579
Iron	11.4	3.28	9.0	11.0	13.7
Zinc	5.6	1.49	4.5	5.6	6.6
Ascorbic Acid	15.1	8.67	9.2	14.0	18.7
Thiamin	0.80	0.213	0.66	0.75	0.96
Riboflavin	0.53	0.163	0.41	0.51	0.62
Niacin	5.1	1.31	4.2	5.1	6.0
Pantothenic Acid	1830	503.2	1453	1719	2197
Vitamin B_6	0.63	0.171	0.50	0.62	0.76
Folate	153	51.0	123	141	171
Vitamin B_{12}	1.37	1.939	0.44	0.71	1.25
Retinol	176	84.6	110	165	236
Vitamin E	2.39	1.008	1.72	2.16	2.86
SFA	7.62	2.895	5.79	6.75	9.19
PUFA	8.41	3.349	6.19	7.62	9.73
	SCHOOL-AGED CHILDREN (N= 110)				
	Mean	SD	Q1	Median	Q3
Energy	1845	437.5	1518	1841	2107
Protein	54.5	13.10	44.7	53.6	64.0
Fat	40.3	11.01	32.6	38.2	48.2
Calcium	854	242.9	670	825	966
Iron	20.6	5.38	17.4	20.0	23.2
Zinc	9.9	2.53	8.2	9.8	11.3
Ascorbic Acid	22.1	14.20	13.6	19.2	26.6
Thiamin	1.41	0.355	1.15	1.38	1.63
Riboflavin	0.82	0.211	0.65	0.79	0.92
Niacin	8.8	2.12	7.3	8.8	10.0
Pantothenic Acid	2705	684.3	2170	2657	3051
Vitamin B_6	1.08	0.288	0.89	1.04	1.25
Folate	248	79.6	194	230	287
Vitamin B_{12}	1.42	1.848	0.46	0.77	1.54
Retinol	246	128.8	162	218	305
Vitamin E	3.30	1.304	2.24	3.14	3.99
SFA	10.88	3.372	8.62	10.22	12.39
PUFA	12.89	4.214	9.89	12.29	15.42

Table 6.5: Distributions of men's and non-pregnant/non-lactating women's intakes of selected nutrients.

MEN (N= 148)	Mean	SD	Q1	Median	Q3
Energy	3001	729.6	2522	3004	3385
Protein	81.7	18.50	68.2	81.6	91.6
Fat	57.7	15.71	46.8	54.9	64.6
Calcium	1343	363.1	1091	1326	1519
Iron	36.3	10.77	29.4	35.6	42.8
Zinc	14.8	3.56	12.3	14.9	17.1
Ascorbic Acid	89.1	60.84	42.2	70.5	125.5
Thiamin	2.20	0.559	1.83	2.17	2.53
Riboflavin	1.33	0.351	1.10	1.28	1.50
Niacin	16.8	5.10	13.1	16.1	19.9
Pantothenic Acid	4319	1051.7	3612	4230	4889
Vitamin B_6	2.05	0.652	1.59	1.98	2.45
Folate	408	131.1	322	392	483
Vitamin B_{12}	2.21	2.592	0.82	1.40	2.31
Retinol	341	155.9	234	323	419
Vitamin E	4.62	1.895	3.28	4.24	5.37
SFA	15.40	4.527	12.54	14.74	17.50
PUFA	18.39	6.380	14.08	17.05	21.17

NON-PREGNANT/NON-LACTATING WOMEN (N= 103)	Mean	SD	Q1	Median	Q3
Energy	2455	711.7	2018	2361	2690
Protein	70.5	22.35	57.1	66.6	80.1
Fat	49.9	15.83	38.4	47.8	56.2
Calcium	1144	429.3	902	1068	1301
Iron	28.8	10.15	23.0	26.6	32.4
Zinc	12.7	4.09	10.4	12.0	14.3
Ascorbic Acid	53.1	38.66	29.2	40.4	65.6
Thiamin	1.87	0.680	1.51	1.76	2.11
Riboflavin	1.09	0.412	0.87	1.03	1.23
Niacin	13.0	4.19	10.3	11.9	14.4
Pantothenic Acid	3604	1195.1	2887	3326	4038
Vitamin B_6	1.58	0.550	1.22	1.49	1.81
Folate	343	166.1	238	306	407
Vitamin B_{12}	1.89	2.588	0.53	1.04	2.08
Retinol	316	200.3	185	275	389
Vitamin E	4.06	1.955	2.75	3.71	4.79
SFA	13.50	4.738	10.19	12.44	15.29
PUFA	15.89	5.708	11.58	15.00	18.25

Table 6.6: Distributions of pregnant and lactating women's intakes of selected nutrients.

	PREGNANT WOMEN (N= 96)				
	Mean	SD	Q1	Median	Q3
Energy	2415	542.9	2031	2322	2724
Protein	69.6	16.16	57.7	68.0	77.0
Fat	51.3	15.543	39.0	50.8	59.3
Calcium	1118	321.1	916	1052	1272
Iron	27.6	6.74	23.3	26.3	32.1
Zinc	12.6	3.08	10.6	11.9	14.2
Ascorbic Acid	42.9	32.87	23.1	33.6	53.3
Thiamin	1.81	0.463	1.49	1.75	2.08
Riboflavin	1.08	0.299	0.86	1.02	1.23
Niacin	12.0	2.98	10.0	11.5	13.5
Pantothenic	3542	981.7	2865	3418	4048
Vitamin B_6	1.50	8.381	1.24	1.43	1.66
Folate	314	109.1	242	298	356
Vitamin B_{12}	2.08	3.667	0.58	1.01	2.08
Retinol	309	151.6	201	275	401
Vitamin E	4.26	1.958	2.90	3.75	5.15
SFA	13.64	4.454	10.12	12.84	16.29
PUFA	16.67	6.156	12.12	15.25	20.56

	LACTATING WOMEN (N= 154)				
	Mean	SD	Q1	Median	Q3
Energy	2648	651.3	2230	2605	3026
Protein	75.1	18.48	62.0	74.1	85.6
Fat	55.6	17.18	44.6	53.6	62.1
Calcium	1215	339.6	993	1179	1407
Iron	30.2	8.45	24.5	28.7	35.9
Zinc	13.7	3.57	11.2	13.4	15.8
Ascorbic Acid	47.6	32.28	21.3	38.0	61.7
Thiamin	1.97	0.498	1.62	1.93	2.31
Riboflavin	1.15	0.329	0.93	1.13	1.28
Niacin	13.4	4.17	10.5	12.8	15.5
Pantothenic	3817	1017.5	3101	3743	4369
Vitamin B_6	1.63	0.467	1.30	1.59	1.89
Folate	346	120.1	259	338	398
Vitamin B_{12}	1.85	3.118	0.52	1.05	1.67
Retinol	304	152.4	193	279	387
Vitamin E	4.64	2.08	3.13	4.20	5.66
SFA	14.63	4.892	12.08	13.59	16.67
PUFA	18.41	7.06	13.58	17.28	21.25

pregnancy (using the second trimester recommendation, p. 87) and 72 g/day in lactation (using the 0-6 months recommendation, p. 89).

In general the mean intakes of energy were exactly as recommended for preschoolers and 109% of the recommendations for schoolers (Table 6.7). However, the schooler's recommendation is based on actual intakes of schoolers in both developed and developing countries, and may well underestimate needs in the latter. Protein intakes were twice the RDA for both groups of children and were ample even in the lowest quartile. Total iron, thiamin and folate intakes exceeded the RDA and are mostly consumed in *tortillas*. Calcium and zinc intakes were around 60% of the RDA for preschoolers. However, most schoolers met, or nearly met, the RDA for these nutrients. The median intakes of ascorbic acid, riboflavin, niacin, pantothenic acid, vitamin B_6, vitamin B_{12}, retinol and vitamin E were only one third to two thirds of the RDA for both groups. It should be noted that the Solís population has a very high prevalence of anemia probably caused by both iron and vitamin B_{12} deficiency (Chapter Eight). In a follow-on study of the preschoolers conducted in 1991, there was a high prevalence of low serum retinol as well [5]. Thus, rather than being at risk of energy or protein deficiency, the Solís children are at greatest risk of vitamin deficiencies, especially ascorbic acid, retinol and vitamin E, and vitamin B_{12} in the case of schoolers. Zinc and calcium intakes are low for preschoolers. However, poor availability of most minerals is to be suspected due to the high fiber and phytate intakes as will be discussed below.

Energy and protein intakes of adult men are generally at or above the recommended levels Table 6.8). Iron intake is very high, due to the consumption of *pulque* which contains a substantial amount, as well as *tortillas*. The most probable vitamin deficiencies are vitamin B_{12}, retinol and vitamin E.

NPNL women's energy and protein intakes are also adequate. Median values for energy in pregnancy and lactation are only about 90% of those recommended, but the recommendation assumes no fall in physical activity compared to the NPNL state. It is unlikely that the availability of dietary energy is inadequate for most pregnant and lactating women, based on the fact that energy intakes increase substantially during lactation when the same women are followed longitudinally (Chapter Eleven). Median mineral intakes also meet recommended levels except for zinc in lactation, but again bioavailability is questionable. Thiamin and folate intakes are satisfactory (although in pregnancy folate does not meet the RDA) but the consumption of all other vitamins fails to meet recommendations. The situation is particularly poor for vitamins B_{12}, retinol and E. In spite of the higher food intake of the lactating women, vitamin intakes are generally most inadequate in this group.

The Importance of Bioavailability and Food Patterns

From the preceding information in this chapter it is evident that where an individual ranks in terms of their intake of animal vs plant products is likely to have a major impact on the adequacy of their mineral and vitamin intake, and on mineral bioavailability from their diet. This

Table 6.7: Distributions of children's intakes of the percent recommended for selected nutrients.

PRESCHOOLERS (N= 87)

	Mean	SD	Q1	Median	Q3
Energy	99.4	24.74	82.3	96.3	113.8
Protein	218.2	52.89	178.9	218.1	254.1
Calcium	62.0	17.79	49.9	60.5	72.4
Iron	114.2	32.80	89.8	109.9	137.2
Zinc	55.9	14.92	45.4	56.3	65.7
Ascorbic Acid	37.8	21.67	23.1	35.1	46.9
Thiamin	114.8	30.44	93.8	107.8	136.5
Riboflavin	66.7	20.42	51.6	63.5	77.5
Niacin	56.5	14.54	45.7	56.4	67.0
Pantothenic Acid	61.0	16.77	48.4	57.3	73.2
Vitamin B_6	62.8	17.12	50.4	61.8	75.6
Folate	305.9	102.09	245.8	281.3	341.8
Vitamin B_{12}	195.8	277.02	62.2	101.9	179.1
Retinol	44.0	21.15	27.4	41.3	59.0
Vitamin E	39.9	16.81	28.7	36.0	47.7

SCHOOL-AGED CHILDREN (N=110)

	Mean	SD	Q1	Median	Q3
Energy	108.9	25.84	89.7	108.7	124.5
Protein	208.2	49.99	170.8	204.5	244.5
Calcium	106.7	30.36	87.1	103.2	120.7
Iron	206.2	53.83	173.8	199.9	231.5
Zinc	98.8	25.28	81.7	98.4	113.2
Ascorbic Acid	49.0	31.55	30.2	42.7	59.1
Thiamin	140.8	35.54	115.1	137.8	162.5
Riboflavin	68.0	17.61	54.0	66.0	76.9
Niacin	68.0	16.31	56.0	67.5	76.8
Pantothenic Acid	67.6	17.11	54.3	66.4	76.3
Vitamin B_6	77.3	20.57	63.3	74.5	89.6
Folate	247.9	79.62	194.0	230.2	286.8
Vitamin B_{12}	101.7	132.01	32.9	54.7	110.3
Retinol	35.1	18.40	23.1	31.1	43.5
Vitamin E	47.1	18.63	32.0	44.8	57.0

Table 6.8: Distributions of men's and non-pregnant/non-lactating women's intakes of the percent recommended for selected nutrients.

MEN (N=148)

	Mean	SD	Q1	Median	Q3
Energy	102.5	24.93	86.2	102.6	115.6
Protein	129.6	29.64	108.3	129.5	145.4
Calcium	166.3	47.05	135.2	165.2	189.9
Iron	352.5	107.76	293.8	353.7	427.7
Zinc	98.8	23.72	82.3	99.2	113.8
Ascorbic Acid	148.1	101.50	70.3	117.5	209.2
Thiamin	148.4	39.39	121.7	145.9	168.7
Riboflavin	79.4	21.66	65.3	76.3	90.0
Niacin	89.6	29.05	69.7	85.3	105.5
Pantothenic Acid	108.0	26.28	90.3	105.8	122.2
Vitamin B_6	102.3	32.60	79.6	98.8	122.7
Folate	204.1	65.64	161.2	196.0	241.4
Vitamin B_{12}	110.0	129.74	40.6	69.5	115.7
Retinol	34.0	15.59	23.4	31.7	41.9
Vitamin E	46.2	19.02	32.8	42.4	53.7

NON-PREGNANT/NON-LACTATING WOMEN (N=101)

	Mean	SD	Q1	Median	Q3
Energy*	100.4	29.10	82.5	96.5	110.0
Protein*	140.9	44.72	114.1	133.1	160.2
Calcium	136.5	49.92	107.0	128.4	155.7
Iron	191.5	68.29	153.3	176.0	215.6
Zinc	105.6	34.73	86.4	99.6	119.5
Ascorbic Acid	89.2	64.88	48.6	70.2	109.4
Thiamin	169.5	62.55	137.5	159.5	187.4
Riboflavin	84.8	33.18	66.7	78.9	94.8
Niacin	87.0	28.88	68.8	79.1	96.2
Pantothenic Acid*	90.1	29.88	72.2	83.1	101.0
Vitamin B_6*	98.7	34.31	76.5	93.4	113.2
Folate*	190.3	92.28	132.1	170.0	226.3
Vitamin B_{12}*	94.7	129.38	26.6	51.8	103.8
Retinol	39.9	25.39	23.1	34.4	51.1
Vitamin E*	50.8	24.44	34.4	46.4	59.9

*N=103

Table 6.9: Distributions of pregnant and lactating women's intakes of the percent recommended for selected nutrients.

PREGNANT WOMEN (N=96)

	Mean	SD	Q1	Median	Q3
Energy	94.1	21.34	79.5	91.1	107.1
Protein	111.0	26.00	89.4	108.5	124.2
Calcium	93.1	26.76	76.3	87.7	106.0
Iron	92.0	22.45	77.6	87.7	107.1
Zinc	83.3	20.38	69.7	78.6	94.2
Ascorbic Acid	59.9	45.91	31.8	48.0	73.7
Thiamin	120.3	30.72	99.4	116.8	138.8
Riboflavin	67.1	18.58	53.5	63.9	76.6
Niacin	69.7	17.19	55.3	67.4	79.1
Pantothenic Acid	88.5	24.54	71.6	85.4	101.2
Vitamin B_6	68.1	17.32	56.6	65.0	75.6
Folate	78.6	27.29	60.4	74.6	89.1
Vitamin B_{12}	94.3	166.66	26.2	46.1	94.5
Retinol	37.8	19.01	24.4	34.0	49.3
Vitamin E	42.6	19.58	29.0	37.5	55.2

LACTATING WOMEN (N=154)

	Mean	SD	Q1	Median	Q3
Energy	92.6	22.77	77.9	91.7	105.8
Protein	104.3	25.66	86.1	103.0	118.9
Calcium	101.2	28.30	82.7	98.3	117.3
Iron	201.6	56.34	163.5	191.2	239.4
Zinc	78.3	20.68	64.9	75.0	90.9
Ascorbic Acid	51.3	34.91	23.3	40.4	68.1
Thiamin	123.0	31.14	101.4	120.4	144.2
Riboflavin	65.4	18.55	53.7	65.0	72.8
Niacin	67.0	20.87	52.4	64.0	77.5
Pantothenic Acid	95.4	25.44	77.5	93.6	109.2
Vitamin B_6	77.6	22.22	61.7	75.8	90.2
Folate	128.1	45.05	96.6	125.0	147.8
Vitamin B_{12}	71.3	119.91	20.1	40.4	64.2
Retinol	24.2	12.15	15.6	21.8	31.1
Vitamin E	40.2	17.84	27.3	36.3	48.8

in turn may affect growth and other aspects of development; throughout later chapters in this report it becomes apparent that dietary quality is an important predictor of several functions, and especially of children's growth which is retarded from an early age in these communities (Chapters Five and Fourteen). For these reasons we compared the intake of nutrients (including energy), specific foods and food groups, and nutrient bioavailability to the attained size of the Solís preschoolers and schoolers. More detailed analyses of predictors of children's size and growth are presented in Chapter Fourteen; the purpose here is simply to use children's size as an outcome measure against which to explore different methods of expressing food intake data. These analyses have been published elsewhere [6].

Nutrient Intake and Children's Size

The following analyses were conducted on data from 87 preschoolers and 110 schoolers, for each of whom at least 8 days of food intake data are available. Summary measures of habitual intake for preschoolers were calculated using intake data during the 12 months preceding the 30 month measurement of weight and length. Similarly, the mean intake of the each schooler was calculated for the 12 month period preceding the final measure of weight and height (which occurred between 8 and 9 years of age). Weight, length and height measures were converted to Z-scores to account for any age differences at time of measurement.

Because food, and especially nutrient, intake is rarely distributed normally, Spearman rank-order correlations were used to explore the relationships between the intake of specific nutrients and children's attained size. These correlations are most resistent to outliers, distribution problems, and non-linear relationships.

The results in Table 6.10 indicate that neither the average daily energy intake nor the average daily protein intake during the previous 12 months was related to the attained weight, length or weight-for-length of the children. This reflects the generally adequate intakes of these nutrients. Dietary retinol was positively related to the Z-score for height at both ages, and for weight in schoolers. As discussed below, these significant correlations can probably be explained by a dietary pattern that contains more retinol, rather than by the actual intake of this nutrient. Weight-for-height Z-scores were not associated with the intake of any nutrient.

Intake of Specific Foods and Size

It would appear from the above analyses that the intake of single nutrients is a poor predictor of children's size. However, a finding that is developed throughout this report (e.g. Chapters Fourteen to Eighteen) is that a number of functional indicators of nutritional status (specifically growth and cognitive performance) are significantly correlated with the children's intake of *animal products* (expressed as either the percent of total energy or of total protein from these foods). Energy and protein proved to be inter-changeable as variables because the intake of one is very highly correlated with the intake of the other.

Table 6.10: Spearman correlations between nutrient intake and size.

	Preschoolers (N=83)			Schoolers (N=89)		
	Height Z-score	Weight Z-score	Wt/Ht Z-score	Height Z-score	Weight Z-score	Wt/Ht Z-score
Energy	-.18	-.17	-.05	.15	.12	-.04
Protein	-.01	-.05	-.04	.17	.16	.00
Calcium	-.06	-.05	.05	.17	.14	.04
Iron	-.21	-.19	-.08	.11	.05	-.14
Thiamin	-.16	-.15	-.06	.09	.05	-.10
Riboflavin	.12	.05	-.02	.20	.20	.04
Niacin	-.04	-.07	-.06	.16	.09	-.15
Ascorbic	-.19	.12	.01	.25[a]	.19	-.01
Retinol	.26[a]	.21	.07	.29[b]	.31[b]	.15
Zinc	-.08	-.16	-.10	.06	.06	-.08

[a]$p<0.05$, [b]$p<0.01$

These associations between intake of animal foods and children's growth and development raise many questions. For example, are there specific nutrients in animal products that correlate with children's growth? Are the nutrients contained in animal products more available for absorption? Alternatively, are animal products simply a marker for a better diet in general? With these questions in mind, the following analyses were designed to explore in greater detail why the intake of animal products appears to be an important marker of nutritional status. The "food group" variables explored here were: the total percent of energy obtained from all animal products as well as from meat, dairy products and eggs separately; and the total percent of energy from all plant sources as well as from *tortillas*, legumes, other vegetables, fruits, and "other plants."

Table 6.11 shows the Spearman correlations between children's Z-scores and their average intake of specific food groups during the previous 12 months. It is evident that the usual diet of taller children contains more animal products (especially meat and milk) and fewer *tortillas* than the diet of shorter children. Neither weight nor weight-for-length was associated with the intake of these foods. A similar pattern was seen in schoolers, this time with animal products and fruits also predicting higher weight and weight-for-height, and *tortilla* and legume intake being associated with smaller size.

Table 6.11: Spearman's correlations between energy from food groups and size.

	Preschoolers (N=83)			Schoolers (N=89)		
	Height Z	Weight Z	Wt/Ht	Height Z	Weight Z	Wt/Ht
Animal Kcal						
% Meat	.21	.10	-.06	.14	.29[b]	.25[b]
% Dairy	.29[b]	.13	-.02	.20	.32[b]	.32[b]
% Eggs	-.05	-.06	-.08	.13	.09	-.06
% All	.32[b]	.19	.02	.12	.23[a]	.20
Plant Kcal						
% *Tortillas*	-.29[b]	-.20	-.00	-.11	-.18	-.16
% Legumes	-.16	-.14	-.18	-.31[b]	-.39[c]	-.24[a]
% Veg	.16	.09	-.02	.17	.12	-.05
% Fruits	.09	.06	.05	.28[b]	.27[a]	.12
% Other	.15	.12	.03	.16	.24[a]	.19
% All	-.32[b]	-.19	-.02	-.12	-.23[a]	-.20

[a]$p<0.05$, [b]$p<0.01$, [c]$p<0.001$

To summarize these analyses, we see a much stronger association between the intake of specific foods and children's size than we did between the nutrients and the anthropometric measures. The general pattern is for animal products, and sometimes fruits and "other plant" products, to predict better growth, while children eating a greater proportion of *tortillas* and legumes grew less well.

Analysis of Dietary Patterns in the Solís Valley.

Because the above results suggest a link between dietary pattern and functional nutritional outcomes, further analyses were done to provide a better description of the dietary patterns of Solís children. This task was approached in three separate ways. First, we calculated the Spearman's rank-order correlations among the food group variables. Table 6.12 shows the results for the preschoolers and schoolers. A higher intake of animal products signifies more consumption of meat, dairy products, and to a lesser extent eggs. Dairy products are most strongly associated with the intake of kcal from animal sources. It is also apparent that those children eating more animal products, and especially meat and dairy products, tend to consume fewer *tortillas* and legumes but more fruits and other plant products.

Table 6.12: Spearman correlations among food group[1] variables.

PRESCHOOLERS (N=87)

	Animal	Meat	Dairy	Eggs	Plant	Tort	Legume	Veg	Fruit	Other Plant
Animal	--									
Meat	.59[c]	--								
Dairy	.82[c]	.31[b]	--							
Eggs	.23[a]	.03	-.07	--						
Plant	--	-.59[c]	-.82[c]	-.23[a]	--					
Tortillas	-.75[c]	-.48[c]	-.61[c]	-.21[a]	.75[c]	--				
Legumes	-.21[a]	-.26[a]	-.12	-.06	.21[a]	.11	--			
Vegetables	-.03	.15	-.21[a]	.07	.03	.04	.11	—		
Fruits	.47[c]	.32[a]	.42[c]	.16	-.47[c]	-.44[c]	-.04	.01	—	
Other Plant	.45[c]	.30[b]	.36[c]	.17	-.45[c]	-.87[c]	-.21[a]	-.14	.25[a]	—

SCHOOLERS (N=110)

	Animal	Meat	Dairy	Eggs	Plant	Tort	Legume	Veg	Fruit	Other Plant
Animal	--									
Meat	.74[c]	--								
Dairy	.73[c]	.33[b]	--							
Eggs	.40[c]	.12	.25[b]	--						
Plant	--	-.74[c]	-.73[c]	-.40[c]	--					
Tortillas	-.68[c]	-.40[c]	-.64[c]	-.31[b]	.68[c]	--				
Legumes	-.26[b]	-.26[b]	-.16	-.13	-.13	-.02	--			
Vegetables	.02	.10	-.13	.08	-.02	.07	-.11	—		
Fruits	.49[c]	.34[c]	.32[c]	.36[c]	-.49[c]	-.42[c]	-.21[a]	.16	—	
Other Plant	.52[c]	.27[b]	.55[c]	.30[b]	-.52[c]	-.92[c]	-.20[a]	-.10	.37[c]	—

[1] Variables represent the mean % of energy intake from each food source.
[a]p<.05 [b]p<.01 [c]p<.001

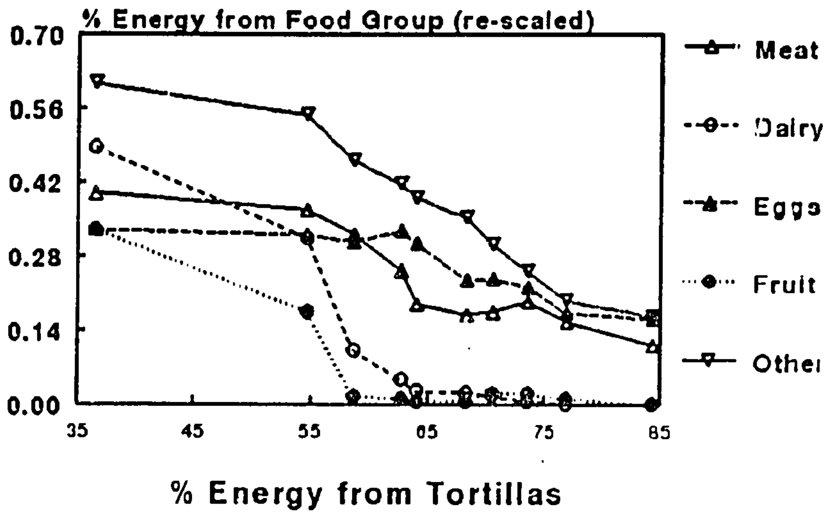

Figure 6.1: School-aged child's intake of energy from meat, dairy products, fruit, eggs, and 'other plant' foods in relation to *tortillas* (values on the vertical axis have been re-scaled).

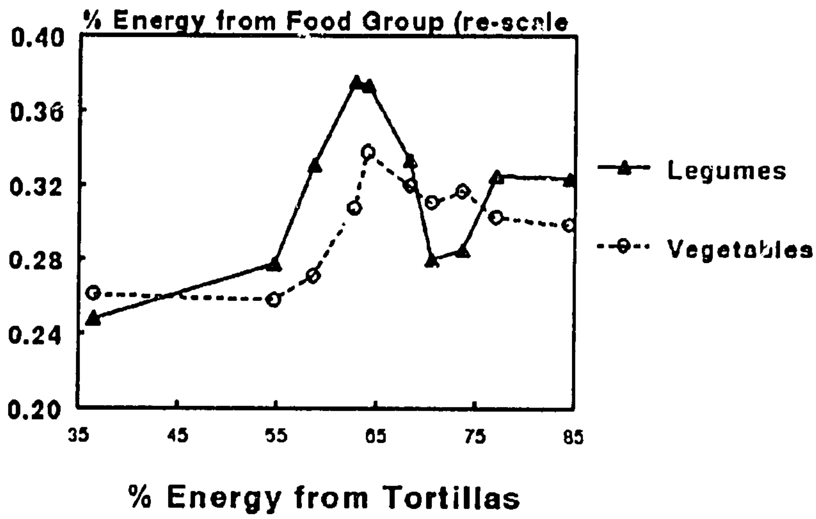

Figure 6.2: School-aged child's intake of energy from legumes and vegetables in relation to *tortillas* (values have been re-scaled).

Table 6.13: Rotated factor patterns for principal components analyses with VARIMAX rotations: food group variables[a].

Food	Preschoolers (N=87) Factor 1	Preschoolers (N=87) Factor 2	Schoolers (N=110) Factor 1	Schoolers (N=110) Factor 2
Tortillas	**-.88**	-.32	**-.95**	-.16
Vegetables	-.38	**.83**	-.26	**.75**
Legumes	**-.44**	.19	-.12	**-.56**
Dairy	**.82**	-.00	**.85**	.14
Other Plant	**.75**	.10	**.90**	.08
Fruit	**.60**	.21	**.52**	**.54**
Meat	**.44**	**.53**	.27	**.51**
Eggs	.14	.37	.15	**.44**
Eigenvalue	3.01	1.22	2.22	1.36

[a] Mean % of daily energy intake from each food source.

Table 6.14: Comparison of Spearman's correlations between the factor one score, the % of energy from *Tortillas*, and nutrient intake[*].

	Preschoolers (N=87) Factor 1	Preschoolers (N=87) Tortillas	Schoolers (N=110) Factor 1	Schoolers (N=110) Tortillas
Iron	-.46[c]	.57[c]	-.28[b]	.34[c]
Retinol	.38[c]	-.41[c]	.19[a]	-.27[b]
Thiamin	-.33[b]	.40[c]	-.16	.24[a]
Zinc	-.30[b]	.38[c]	-.25[a]	.30[b]
Kcal	-.13	.27[b]	-.08	.16
Calcium	-.07	.24[a]	-.15	.24[b]
Niacin	-.17	.23[a]	-.08	.09

[a] $p<0.05$, [b] $p<0.01$, [c] $p<0.001$

[*] No correlations with protein, riboflavin, and ascorbic acid were statistically significant at $p<0.05$.

As a second step, the mean % of energy from the different food groups was plotted against the % of energy from *tortillas* (Figures 6.1 and 6.2). The plots are so-called median traces, a graphical technique advocated by Tukey and others [7]. To obtain the plotted values, the X values were ordered according to value and partitioned into groups of approximately equal size. For each group, the medians of X and Y were then calculated. Next, the median Y values were smoothed to improve interpretability (first using running groups of three and then running groups of two).

To improve presentation; the Y values in Figures 6.1 and 6.2 have been re-scaled. Given the widely varying contribution of the different food groups to dietary energy, re-scaling becomes a necessary procedure if all the food groups are to be plotted on the same graph [8]. The Y values were rescaled by dividing the child's food group value by the sample food group inter-quartile range (3rd quartile minus 1st quartile). The resulting values may be plotted on a single graph, although they are presented here in two graphs for clarity.

Returning to Figures 6.1 and 6.2, the X axis represents the mean % of energy consumed as *tortillas* for each schooler. The Y axis is the average % of each of the other food groups consumed. Figure 6.1 shows that those schoolers who consume proportionately more *tortillas* eat remarkably less dairy products and fruit, and substantially less meat, and "other" plant products. It is notable that the intake of dairy products falls to almost nothing at the point when the % of energy from *tortillas* exceeds approximately 55%, which is the case in about 75% of the schoolers (Figure 6.1). By comparison, Figure 6.2 shows that the proportion of dietary energy from legumes, eggs, and vegetables stays fairly stable with respect to the % of energy from *tortillas,* although eggs do show a pattern that is similar to that seen for meat and dairy (the effect being less dramatic). In the case of vegetables (tomatoes, onions, chiles, and gathered plants) and legumes, increased reliance on *tortillas* for dietary energy is associated with a somewhat increased % of dietary energy from these two food groups. The patterns in Figures 6.1 and 6.2 were similar for preschoolers (not shown).

As a third step in investigating the interrelationships between the food group variables, principal components analysis was employed. The first analyses, for both the schoolers and preschoolers, resulted in two factors with eigenvalues greater than 1.0. After plotting the initial eigenvalues and examining the three factor solutions, the two factor models were selected as the best. Table 6.13 gives the results of these two factor models. The first factor can be seen reflecting the continuum of dietary patterns that were observed in the former analyses. In the case of the preschoolers, children who have a lower (as indicated by the negative loadings) intake of *tortillas* (-.88), and to a lesser extent legumes (-.44), have a higher intake of dairy (.82) products, other vegetable foods (.75), fruit (.60) and meat (.44). The second factor has high loadings for meat and vegetables.

The pattern for the schoolers is similar to that seen for the preschoolers. A high proportion of energy from *tortillas* is associated with less consumption of other vegetable foods (.90), dairy (.85), and fruit (.52). The second factor has high loadings for vegetables (.75), fruit (.53), meat (.51), and eggs (.44).

In general, all three approaches described here (the correlation matrices, the plots, and the principal components analyses) show that a continuum of diet exists in the Solís Valley that ranges from individuals who are very highly dependent on *tortillas* to those who have a much more complex diet in which dairy products, meat, fruit and "other" plant products are consumed in larger quantities.

Given its value in the factor loading, it appears that the percentage of a child's energy intake that is consumed as *tortillas* might act as an indicator of poor diet quality in general. To test this, we compared each child's Factor One score, and their intake of *tortillas*, against their nutrient intake (Table 6.14). As expected, the nutrients showed similar correlations with the Factor One score (although the signs are reversed due to the negative correlation between *tortilla* consumption and Factor One). Surprisingly, *tortilla* intake is strongly *positively* correlated with the intake of iron, thiamin, zinc, energy, calcium and niacin for preschoolers, and to iron, thiamin, zinc and calcium for schoolers. Retinol, on the other hand, is consumed in lower amounts when *tortillas* supply a larger proportion of dietary energy. The positive relationship between retinol intake and children's size (Table 6.1) is probably explained by the lower intake of retinol that results from consuming a larger percent of energy as *tortillas*. The intake of protein, riboflavin and ascorbic acid shows little association with the amount of *tortillas* consumed or with the Factor One score.

On the basis of these results, *tortilla* intake is associated with a *higher* intake of several nutrients. This result is surprising since the analyses above show that *tortilla* intake predicts **poorer** growth. The reason for this apparent contradiction may lie in the bioavailability of nutrients: nutrient composition values for *tortillas* may not reflect the bioavailability of the nutrients. Also, the bioavailability of nutrients from other foods may be poorly modeled given a diet that is heavily dependent on *tortillas*.

Construction of Bioavailability Variables and their Relationship to Children's Size

The construction of bioavailability variables was described in Chapter Three. These include available iron using Monsen's formula [9] which does not account for the negative effects of fiber. Nevertheless, assuming a requirement for absorbable iron of 1 mg/d, the intake of this by preschoolers is particularly low (Table 6.15). To account for the negative effects of fiber on iron absorption, the ratio of fiber to iron (g/mg) was also calculated [10]. Variables that should reflect the bioavailability of zinc include the phytate/zinc molar ratio [11] and the product of (phytate times calcium) divided by zinc [12]. In the diets of Solís children, these ratios exceed the limits (Table 6.15) published in the literature above which zinc absorption is impaired. Although calcium bioavailability from Solís diets is poor [13], no proxy for calcium availability was employed here because there is no theoretical basis on which to believe that it would affect children s growth.

Associations were then explored between the bioavailability variables and the nutritional outcomes. Higher intakes of fiber and phytate relative to iron and zinc were associated with

Table 6.15: Distributions of bioavailability variables[a].

		Preschoolers			Schoolers		
	Limits[b]	Q1	Median	Q3	Q1	Median	Q3
Available Fe (mg)	1.0	.32	.41	.50	.61	.76	.94
Fiber/Fe (g/mg)	1.6	1.1	1.2	1.3	1.2	1.3	1.3
Phytate (mg)		1235	1575	2032	2635	3318	4150
Phytate/Zn	10-20	26	31	34	32	35	38
(Phytate*Ca)/Zn	>200	249	365	454	576	691	872

[a] Q1= 25th percentile, Q2= 50th percentile, Q3= 75th percentile
[b] Limits are from references [8] (available Fe), [9] (fiber/Fe), [10] (phytate/Zn), and [11] (phytate*Ca)/Zn.

Table 6.16: Spearman's correlations between nutrient availability and size.

	Preschoolers (N=83)			Schoolers (N=89)		
	Height Z	Weight Z	Wt/Ht	Height Z	Weight Z	Wt/Ht
Heme Fe	.18	-.03	-.20	.05	.20	.12
Available Fe	-.04	-.13	-.13	.17	.20	-.08
Fiber/Fe	-.20	-.22[a]	-.12	-.12	-.24[a]	-.11
Phytate	-.29[b]	-.25[a]	-.09	.02	-.03	-.12
Phytate/Zn	-.35[b]	-.19	.02	-.11	-.21[a]	.17
(Phytate*Ca)/Zn	-.30[b]	-.23[a]	-.02	-.03	-.03	-.09

[a]$p<0.05$, [b]$p<0.01$

more growth-stunting among preschoolers as reflected in lower height and weight Z-scores at 30 months (Table 6.16). However, preschooler weight-for-height showed little correlation with the bioavailability measures. For schoolers, negative associations were seen between their weights, and ratios of fiber to iron and phytate to zinc.

Not surprisingly both the Factor One score and the *tortilla* intake measure were strongly associated with these bioavailability variables. Children eating more *tortillas*, or who had a

Table 6.17: Comparison of Spearman's correlations between the Factor One score and % energy from *tortillas* with the bioavailability variables.

	Preschoolers (N=87)		Schoolers (N=110)	
	Factor 1	% Tort	Factor 1	% Tort
Phytate/Zn	-.84[b]	.92[a]	-.68[b]	.79[b]
Phytate	-.69[b]	.80[b]	-.48[b]	.57[b]
Fiber	-.66[b]	.65[b]	-.37[b]	.42[b]
(Phytate*Ca)/Zn	-.62[b]	.78[b]	-.46[b]	.57[b]
Fiber/Fe	-.59[b]	.39[b]	-.32[b]	.27[a]
Heme	.35[b]	-.29[a]	.35[b]	-.30[a]
Available Fe	-.17	.27[a]	-.17	.17

[a]$P<0.01$, [b]$P<0.001$

lower Factor One score, had diets with more phytate and fiber, less absorbable iron as indicated by the higher fiber/iron ratio, less available zinc, and less heme iron (Table 6.17).

These negative relationships between indicators of poor nutrient availability and *tortilla* intake may be the explanation for the negative associations seen between *tortilla* intake and children's size.

Potential Confounding Effect of Socioeconomic Status

The relationships described above suggest that the growth-stunting of Solís Valley children reflects the poor *quality*, rather than quantity, of the diet. However, the possible confounding effect of socioeconomic status cannot be ignored. Better dietary quality in the Solís Valley is associated with higher socioeconomic status. As a result, it is possible that the apparent effects of dietary quality on children's growth are in fact a reflection of some other correlate of socioeconomic status.

To investigate this possibility, the partial correlations between selected dietary and nutrient intake variables and children's size were examined controlling for socioeconomic status (SES), using the data on household ownership of material goods and the construction of the house. This use of partial correlations is a conservative approach since SES is allowed to explain variation in children's size that also could be explained by diet. In other words, this approach "over-controls" for the effects of SES, since the effects of a SES-related, higher quality diet are attributed to SES alone.

Table 6.18: Partial correlations (Pearson's) between nutrient availability and size controlling for SES.

	Preschoolers (N=76)			Schoolers (N=88)		
	Height Z-score	Weight Z-score	Wt/Ht Z-score	Height Z-score	Weight Z-score	Wt/Ht Z-score
% Animal	.25[a]	.16	.05	.07	.21[a]	.20
% *Tortillas*	-.24[a]	-.21	-.08	-.14	-.22[a]	-.13
Retinol	.15	.09	.08	.17	.21[a]	.09
Phytate	-.29[b]	-.25[a]	-.12	.06	.01	-.04
Phytate/Zn	-.29[b]	-.19	-.06	-.14	-.24[a]	-.15
(Phytate*Ca)/Zn	-.29[b]	-.24[a]	-.11	.09	.08	.04

[a]$p<0.05$, [b]$p<0.01$

Despite over-controlling for SES, Table 6.18 shows that the relationships between the dietary and bioavailability variables and children's size persist. For preschoolers, sizeable partial correlations are seen between the length Z-scores and % animal kcals (+), % *tortillas* and the phytate variables (-). In the case of the schoolers, the negative correlations of the *tortilla*, phytate and zinc measures with the weight Z-scores remain significant. These results suggest that the apparent effects of dietary quality on children's growth are **not** the result of some unmeasured correlate of socioeconomic status.

Conclusions

We have identified a continuum of dietary patterns in Solís Valley children, that ranges from a high intake of *tortillas* and beans (the lowest quality diets) to a proportionately higher intake of animal products (especially milk), fruits, and plant products such as wheat and rice, oil, root crops, and non-dairy beverages. Children at the more diverse end of this continuum have significantly better growth. However, while the diet that favors these better outcomes would be accepted in traditional nutritional terminology as being of higher quality, it was not identifiably higher in any specific nutrient except retinol, as calculated from food composition tables. Rather, dietary variables that were models of nutrient bioavailability were the best predictors of children's size. Although proxies for bioavailable iron and zinc were used here, and iron and zinc deficiencies are those most commonly associated with impaired growth, these may or may not be *the* growth-limiting nutrients for the Mexican children because the bioavailability of other nutrients is likely to be concomitantly low.

Policy Implications

These results, if they are at all representative of the situation in developing countries, have several implications.

- Average energy and protein intakes met recommended levels for all age and sex groups, and protein intakes were more than adequate. Individuals in these communities do not need more of the *same* food - they need more high quality foods.

- Children's median intake of several vitamins is very low. They consume less than two-thirds the recommended intake of riboflavin, niacin, pantothenic acid, B_6 and B_{12}, and only one third of the recommended amount of vitamin C, retinol and vitamin E. This fact, together with the micronutrient deficiencies described in Chapter Eight, suggests a need to improve the quality of these children's diets, as well as to consider the need for fortification and/or supplements.

- Adults have very low median intakes of vitamin B_{12}, retinol (one third the recommendation) and vitamin E. Women have poor vitamin C intakes, but men consume more of this vitamin in *pulque*. Again, the need for appropriate interventions is clear, especially during pregnancy and lactation.

- Mineral intakes *appear* to be adequate but are undoubtedly not, given the effects of dietary fiber and phytate - which are high in these maize-based diets - on their absorption. Evidence for this was provided by the fact that children's size is negatively related to the extent that their diet consists of high fiber *tortillas* rather than dairy products and fruits and vegetables, as well as the high prevalence of iron deficiency in this population (Chapter Eight). In populations subsisting on high fiber and phytate plant products, such as maize, estimates of mineral bioavailability must be included in surveys of food intake adequacy. Consideration should be given to establishing techniques that lower phytate intake and improve mineral bioavailability; these might range from changing combinations of foods consumed at the same meal (especially for young children), to changing food processing or preparation methods, or to advances in biotechnology.

- These analyses illustrate that it is risky to interpret relationships between *specific* foods or nutrients and nutritional status outcomes without considering the pattern of food substitutions and additions. For example, a high dependence on *tortillas* in these communities also means a low intake of animal products, fruit and vegetables. It is an individual's ranking on the continuum of this dietary pattern that is important for predicting their nutritional status. Dietary patterns will vary from one cultural setting to another, but once the pattern is understood, it is likely that the intake of key foods, such as *tortillas* or animal products in Mexico, will be the best predictors of nutritional status and subsequent functional outcomes. This argues for food intake surveys that focus on specific foods or patterns, rather than attempting to gather quantitative information on the intake of specific nutrients.

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Chapter Seven.
Social Predictors of Dietary Quality

Introduction

In the rural Third World, a variety of social, economic, demographic, and cultural factors affect food intake. Not the least of these are poverty, large families, and low levels of education. In this chapter, we examine some of the factors associated with dietary quality in the Solís Valley. The primary focus is on the household. In the Solís Valley, nearly all food intake occurs within this environment, and the household is a primary means by which resources are organized, and individual needs are met. As will be shown in this chapter, individual food intake in this setting is largely a reflection of household food intake.

Household Dietary Quality and Food Intake

The analyses presented here are for 203 households with 8 days of dietary data during the period January 1985 - September 1985. This period was chosen to correspond to one harvest year (maize usually being harvested in October). Diet data collected from October - December 1984 were not employed because of diet protocol changes. Recipes and the proportion of recipes consumed during the day permit estimates of daily household food intake. The quantity of *masa* and *tortillas* consumed during the recall period was also recorded. Unfortunately, non-recipe foods (such as bananas or white bread) consumed by non-target individuals are missing from these estimates. However, very few foods are eaten in non-recipe form. Daily measures of dietary quality (% energy from *tortillas* and from animal sources) were then calculated. Summary measures were obtained by taking the mean of daily intake.

In addition to dietary quality, the consumption of 18 key foods was investigated. Two measures were created per food: 1) the frequency of consumption of the food, and 2) the median weight consumed when eaten. These foods were selected from the 39 foods most commonly eaten in the valley, and were chosen because of their frequency of consumption and potential nutrient contribution to the diet [1].

Lastly, intra-household variation in dietary quality was examined for 177 households with a preschooler (N=85) or school-aged child (N=106). Daily deviations in individual intake from household intake in the percent energy from *tortillas* and animal products were calculated. Summary measures were created by taking the mean of these deviations for each household.

The Major Independent Variables

Mexico CRSP personnel collected a considerable amount of information on social, economic, demographic, and cultural factors with the potential to affect intakes of foods and nutrients (see Chapter Three).

Household Material Wealth

In the Socioeconomic Questionnaire, information was collected concerning the ownership of material goods, agricultural instruments, and the construction of the house. Principal components analyses were used to identify three factors, the first of which contained high loadings on 10 material goods and features of house construction [1]. A measure of *household material goods* was constructed by summing the variables with high loadings (after adjusting for the distribution).

Household Energy Needs

On the revised dietary recall instrument, the identity of each person attending meals on the recall day was recorded. For each person attending meals during that 24-hour period, an estimate of individual energy need was calculated based on the age, sex, and weight of the individual assuming a moderate level of physical activity [2]. In most cases, the individual's age and sex were known. In those few cases when an individual's weight was unknown, a value based on that individual's age and sex was substituted using a normative estimate of energy need [3]. When both age and sex were missing, the individual's energy need was imputed as 2250 kilocalories per day (the approximate needs of a young adolescent). No adjustments were made for physiological status. For each household, the estimates of individual energy need were summed for the day. The median of all daily measures was then used as an measure of *estimated household energy needs.*

Characteristics of the Parents

Information on the characteristics of the parents was collected in the Socioeconomic, Sociocultural, and Adult Cognition instruments. These variables include separate measures on the mother and father of literacy and schooling, parental aspirations for children's future schooling and occupation, trips from the valley, knowledge of non-valley facts, and the ability to identify a series of development agencies in the valley. In addition, the house, yard, and selected members of the household were rated on general appearance and cleanliness (Chapter Three).

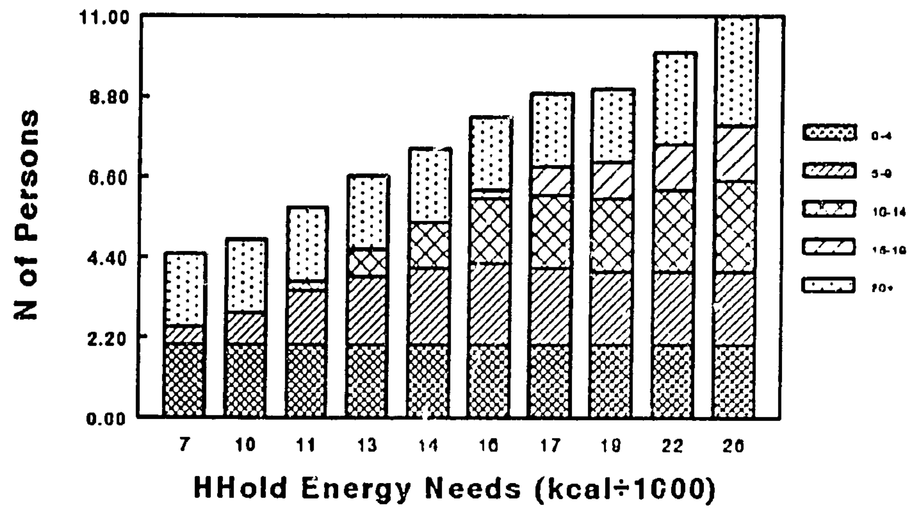

Figure 7.1: Household energy needs and the median number of persons in different age groups.

Household Energy Needs and Energy Intake

Figure 7.1 shows the relationship of household size and composition to estimated household energy needs, plotting the median number of persons of different ages in households according to different levels of estimated household energy needs. The graph shows all levels of household energy needs to have a median of two children, a reflection of the continuing higher fertility of this population. The highest energy needs are for households with teenagers and young adults in addition to younger children.

Table 7.1 presents the descriptive statistics for estimated household energy needs, household energy intake, and the difference between the two measures. In general, household energy intakes were very close to calculated energy needs, although the intakes tended to exceed the estimate. Nevertheless, approximately 35% of households consumed less energy than the estimated needs.

Figure 7.2 shows the relationship between estimated household energy intake and estimated household energy needs (Spearman's correlation, r=0.65). The dashed line indicates the point where estimated needs equal estimated intake. Most household's intakes can be seen to exceed estimated needs. Figure 7.3 shows the smoothed quartiles and medians for the scatterplot in Figure 7.2. Household energy intake can be seen to parallel energy needs until needs reach approximately 18,000 kcal per day. At this point there is a flattening of the curve. This point

Table 7.1: Distribution of household energy intake and energy needs (kcal/day, N=203).

	Mean	SD	Q1	Median	Q3
Household Energy Intake	17632	6177	12922	16599	20989
Household Energy Needs	15573	5752	11054	14864	19276
Household Intake Minus Needs	2059	5485	-649	2274	4820

Table 7.2: Spearman correlations among the percent of dietary energy from *tortillas* for the preschooler, school-aged child, mother, and father.

	% Energy from *Tortillas*		
	Preschooler	Schooler	Mother
	r (N)	r (N)	r (N)
Preschooler	----		
School-Aged Child	0.92 (28)	----	
Mother	0.71 (87)	0.84 (67)	----
Father	0.82 (63)	0.73 (80)	0.80 (146)

coincides with the presence of older teenagers and young adults in the household, and could conceivably be due to 1) lower energy needs than calculated for teenagers, 2) unrecorded food consumption by teens and young adults, or 3) actual lower energy intake in comparison to energy needs. However, Spearman's correlations show little relationship between household energy needs and the energy intakes of preschoolers ($r=-0.15$, $N=87$), school-aged children ($r=-0.07$, $N=107$), mothers ($r=0.02$, $N=201$), or fathers ($r=0.16$, $N=146$).

These results suggest that household energy needs have no effect on the energy intakes of individuals. This finding is consistent with our belief that there is little or no energy insufficiency in this population (Chapter Six). As the dietary energy intake of individuals shows little relationship to any of the functional measures (i.e. anthropometric and psychological measures) employed in this study (Chapters Twelve to Seventeen), and dietary quality is a good predictor of several human functions in this population, the remainder of this chapter concerns dietary quality and the social environment.

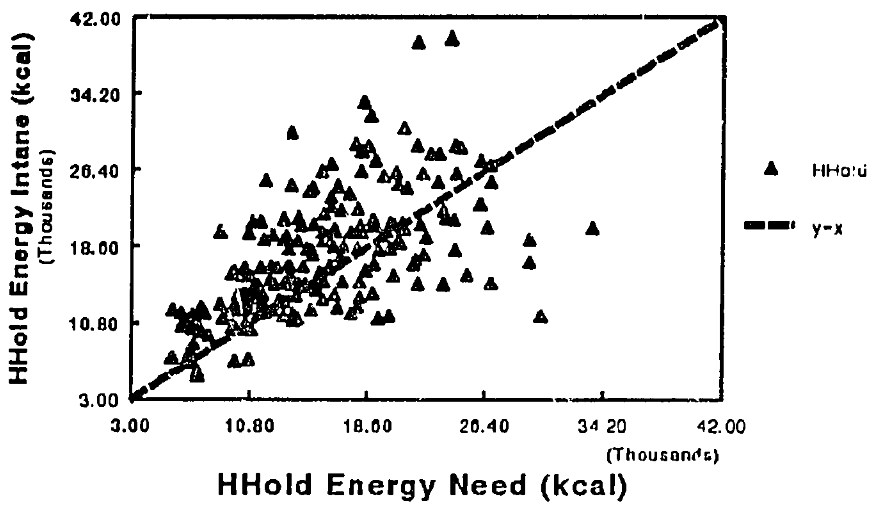

Figure 7.2: Scatterplot of measured household energy intake and estimated household energy needs.

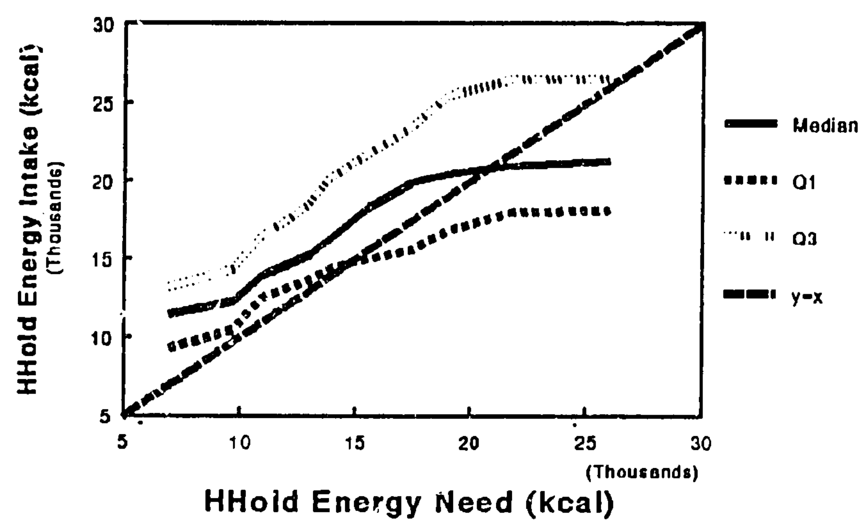

Figure 7.3: Median and quartile traces of measured household energy intake and estimated household energy need.

Household Dietary Quality and Individual Dietary Quality

The best predictor of *individual* dietary quality in this population is *household* dietary quality. Figure 7.4 shows the relationship of the preschooler and schooler diet to the household diet in terms of the percent of total energy from *tortillas* (%TORT). The graph shows little scatter of individual intakes around household intake, 67% of the variance for either preschooler or schooler consumption being explained by household intake.

The relationship of individual intake to household intake is somewhat affected by the inclusion of individual intake in the household measure. However, this effect is probably minor except for the smallest households as evidenced by the large correlations among individual measures of dietary quality. As shown in Table 7.2, the Spearman correlations among individuals for the %TORT ranges from 0.71 (mother-preschooler) to 0.91 (mother-schooler).

Household Energy Needs and Dietary Quality

Figure 7.5 shows the relationship of household intake of maize and non-maize derived energy to household energy needs. The graph shows intakes of maize to increase steadily with larger household energy needs. In contrast to maize-based energy, consumption of non-maize energy increases at a much slower pace. As a result, there is an increase in the proportion of household energy from maize as household energy needs become large. Figure 7.6 shows the smoothed medians and quartiles of this relationship. Reliance on maize can be seen to increase until approximately 20,000 kcal per day (which is about 9 people in the household). At this point, there is a leveling off or reversal of the trend, perhaps due to additional wage-earners in the household. The Spearman's correlation is r=0.30. However, the association would be much stronger across the ascending portion of the range. Figure 7.7 shows the inverse relationship for the percent of energy from animal products (%ANIM)(r=-0.25): household intake of animal products decreases with higher energy needs, and then reverses when there is a larger number of older teenagers or young adults in the household. Spearman's correlations of individual dietary quality with household energy needs provide unsurprising evidence of a negative effect of high energy needs (large households) on the quality of individual's diets (Table 7.3). However, the situation is more complicated as indicated by Figure 7.8. This graph shows the smoothed medians for individual %ANIM (re-scaled for presentation purposes). The effect of household size can be seen to be non-linear: the proportion of the diet from animal sources decreases and then increases with growing household energy needs. On the basis of the plot, the diet of the preschooler appears to be most affected by differences in household size and composition.

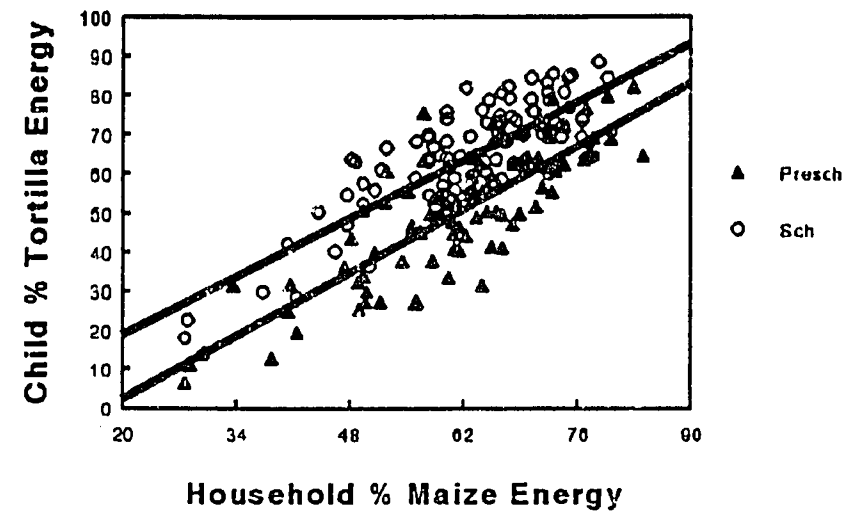

Figure 7.4: The dietary quality of the preschooler and school-aged child vs that of the household with respect to the percent of energy from *tortillas*.

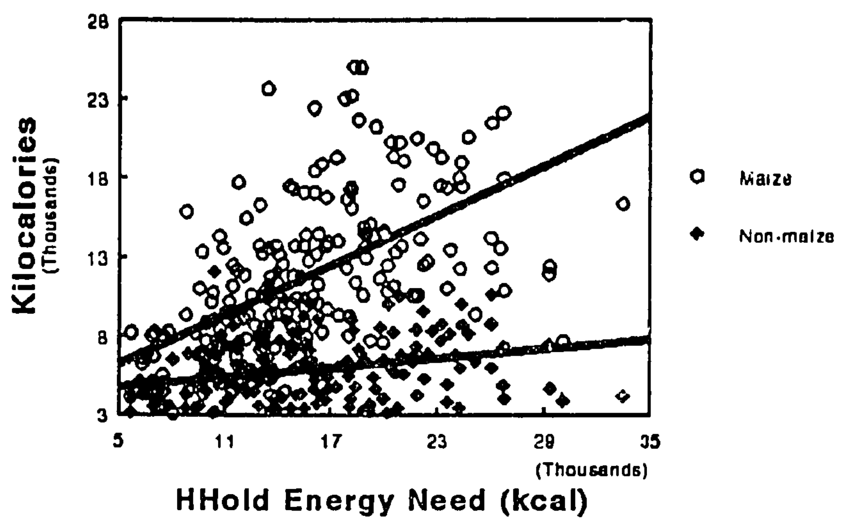

Figure 7.5: Scatter plot of household dietary energy from maize and non-maize sources with respect to household energy needs.

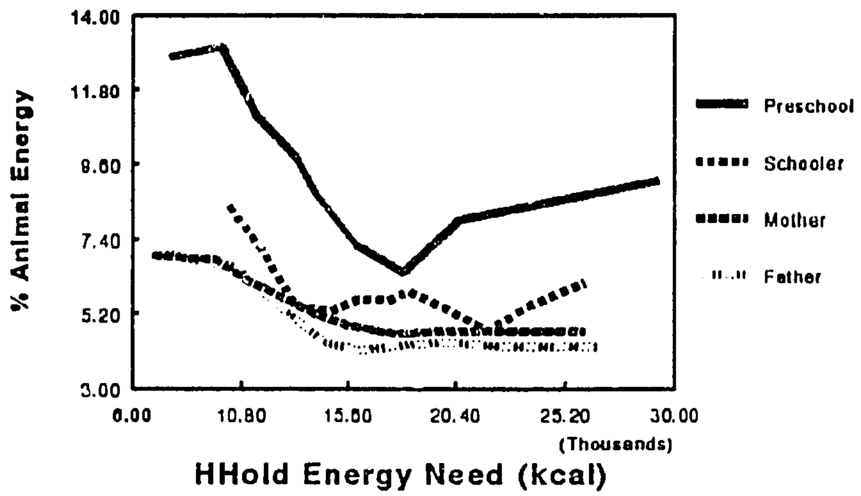

Figure 7.8: The percent of individual dietary energy from animal sources and estimated household energy needs.

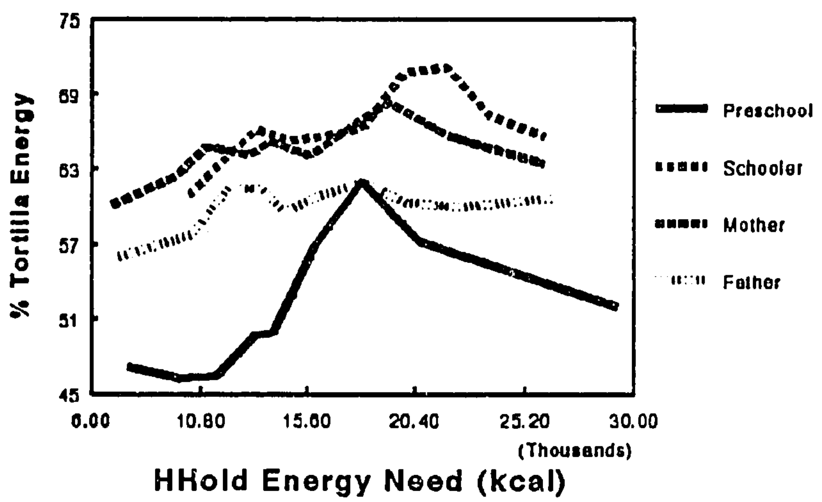

Figure 7.9: The percent of individual dietary energy from *tortillas* and estimated household energy needs.

Table 7.3: Spearman correlations of household energy need with individual energy intake and dietary quality.

	N	Total Energy	% Tortilla	% Animal
Preschooler	87	-0.15	0.32	-0.26
School-Aged Child	107	-0.07	0.24	-0.22
Mother	201	0.02	0.21	-0.22
Father	146	0.16	0.04	-0.25

Table 7.4: Household material wealth and dietary quality of individuals.

	N	%Animal	%Tortillas
Preschoolers	87	0.44	-0.38
Schoolers	107	0.52	-0.52
Mothers	201	0.47	-0.39
Fathers	146	0.54	-0.44

Household Material Wealth and Dietary Quality

Household *material wealth* scores reveal considerable intra-community variation on this economic dimension. Some wealthier households own cars, refrigerators, and gas stoves, while poorer households may have only one bed, no television or radio, and a house with dirt floors and no windows. Nevertheless, none of the households could be considered wealthy by any definition, intra-household variation in wealth representing degrees of poverty by cosmopolitan standards.

There was a near zero correlation (r=0.01) between household material wealth and household energy intake, indicating no relationship between economic situation and energy consumption.

Figure 7.10 shows the relationship of household material wealth to household %ANIM. The plot shows a steady increase in the proportion of animal products in the diet with increasing wealth (r=0.47) Among the wealthiest, there is a much larger variation in the proportion of animal products consumed than seen for poorer households, showing higher wealth to be insufficient to *insure* diets that are appreciably better than in poorer households. Figure 7.10 shows the relationship between household %TORT and household material wealth. There is a

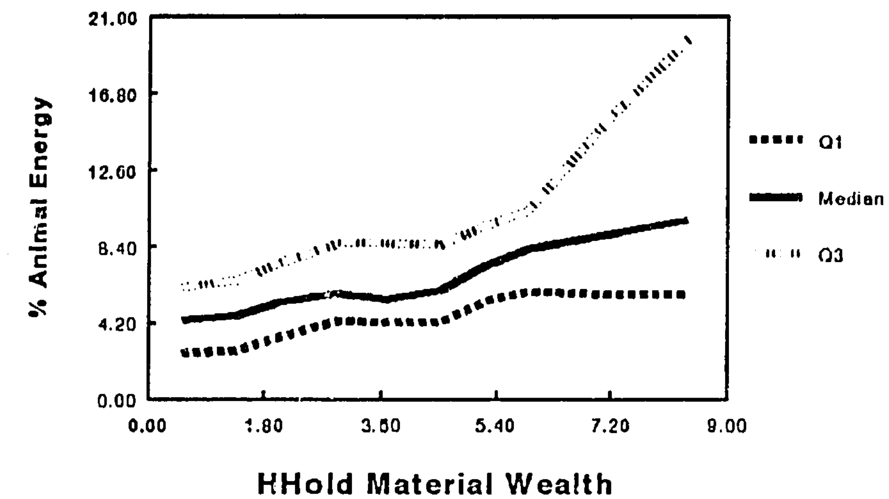

Figure 7.10: Household material wealth and the percent of energy from animal sources.

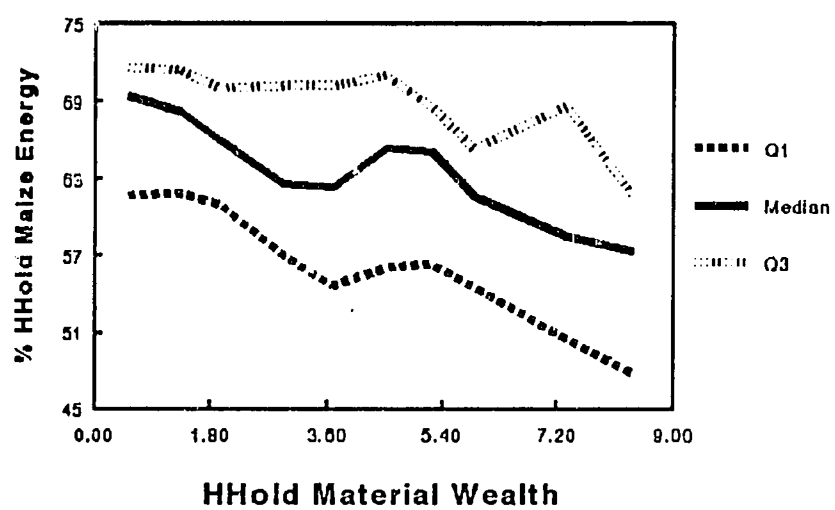

Figure 7.11: Household material wealth and the percent of household energy from *tortillas* and *masa*.

Table 7.5: Multiple regression models predicting the log mean % of household energy from foods of animal origin (log %ANIM) and mean % energy from *tortillas* squared (%TORT²).

	Variables	Parameter	t-statistic	p-value
Log %ANIM	Intercept	2.379	9.84	.0001
(N=203)	HHold Energy Needs (÷ 10000)	-0.9651	-3.27	.0013
	HHold Energy Needs²	0.2257	2.62	.0095
	Household Material Wealth	0.1159	8.51	.0001
	R-square = .32	Root MSE = 0.484		
%TORT²	Intercept	61.600	26.24	.0001
(N=203)	HHold Energy Needs (÷ 10000)	5.026	4.24	.0001
	Household Material Wealth	-6.108	-6.11	.0001
	R-square = .23	Root MSE = 9.53		

steady decline in reliance on *tortillas* for household energy with higher material wealth (r=0.37). Table 7.4 shows the Spearman's correlations between the *individual* dietary quality measures and *household* material wealth: the correlations range from 0.54 (schooler %ANIM) to -0.38 (preschooler %TORT).

Household Energy Needs, Material Wealth, Dietary Quality and Consumption of Key Foods

The combined effects of household energy needs and material wealth on household dietary quality are shown in the multiple regression in Table 7.5. The log of %ANIM was used to straighten the relationship and improve the distribution of the highly skewed variable. Careful modeling showed the best regression model for %ANIM to include a quadratic term to capture the change in direction seen at 20,000 kcal. A quadratic term was not useful for %TORT. No interactions were seen between household material wealth and household energy needs, showing the wealthier and the poorer both to be susceptible to the negative effects of larger household size. Together, household energy needs and material wealth explain 32% of the variation in %ANIM, and 23% of variation in %TORT. Regression modeling employing a change point might have improved the models still more.

Table 7.6: Spearman correlations of estimated household energy needs and material wealth with the consumption frequencies and consumption weights of 18 key foods.

	FREQUENCY			WEIGHT		
	N	Energy	Wealth	N	Energy	Wealth
Beans	203	.13	-.02	202	.46 ‖	-.10
Potatoes	203	-.08	.01	196	.41 ‖	-.07
Squash	125	-.06	.10	60	.40†	-.02
Serrano Chiles	203	.22†	-.04	197	.39 ‖	-.03
Pasta	203	-.07	.17	199	.39 ‖	-.13
Beef	203	-.03	.24‡	142	.31§	.01
Pulque	166	.22†	-.09	129	.28†	-.07
Coffee	203	-.09	.30 ‖	187	.27§	-.04
Tomatoes	203	.03	.34 ‖	200	.23†	.12
Nopales	203	.11	-.02	183	.23†	-.05
Chicken	203	.02	.34 ‖	144	.23†	.05
Eggs	203	-.11	.18	198	.21†	.09
White Bread	203	-.20†	.28 ‖	145	.20	.05
Rice	203	-.03	.17	175	.16	.04
Quelites	123	.13	-.26†	75	.12	.01
Green Tomatoes	203	.15	-.12	179	.12	.15
Dried Broad Beans	166	-.05	.02	76	.12	-.20
Cow's Milk	184	-.12	.44 ‖	92	-.05	.23

* $p<0.01$ † $p<0.005$ ‡ $p<0.001$ § $p<0.0005$ ‖ $p<0.0001$.

A further understanding of the effects of household energy needs and material wealth can be gained by examining the relationship of these variables to the consumption of 18 key foods selected to represent aspects of the Solís Valley diet. Table 7.6 shows the relationship of household material wealth to the frequency of consumption and median weight of consumption of these key foods. The table shows household *material wealth* to have sizeable correlations with the frequency of consumption of tomatoes, coffee, white bread, beef, milk, and chicken. Material wealth has a negative correlation with *quelites* (a gathered wild green). In contrast, household material wealth shows little relationship to the quantity of food consumed (except for milk). In contrast, *household energy needs* show little relationship to the frequency of consumption of foods with the exceptions of serrano chiles, bread (-), and *pulque* (an adult

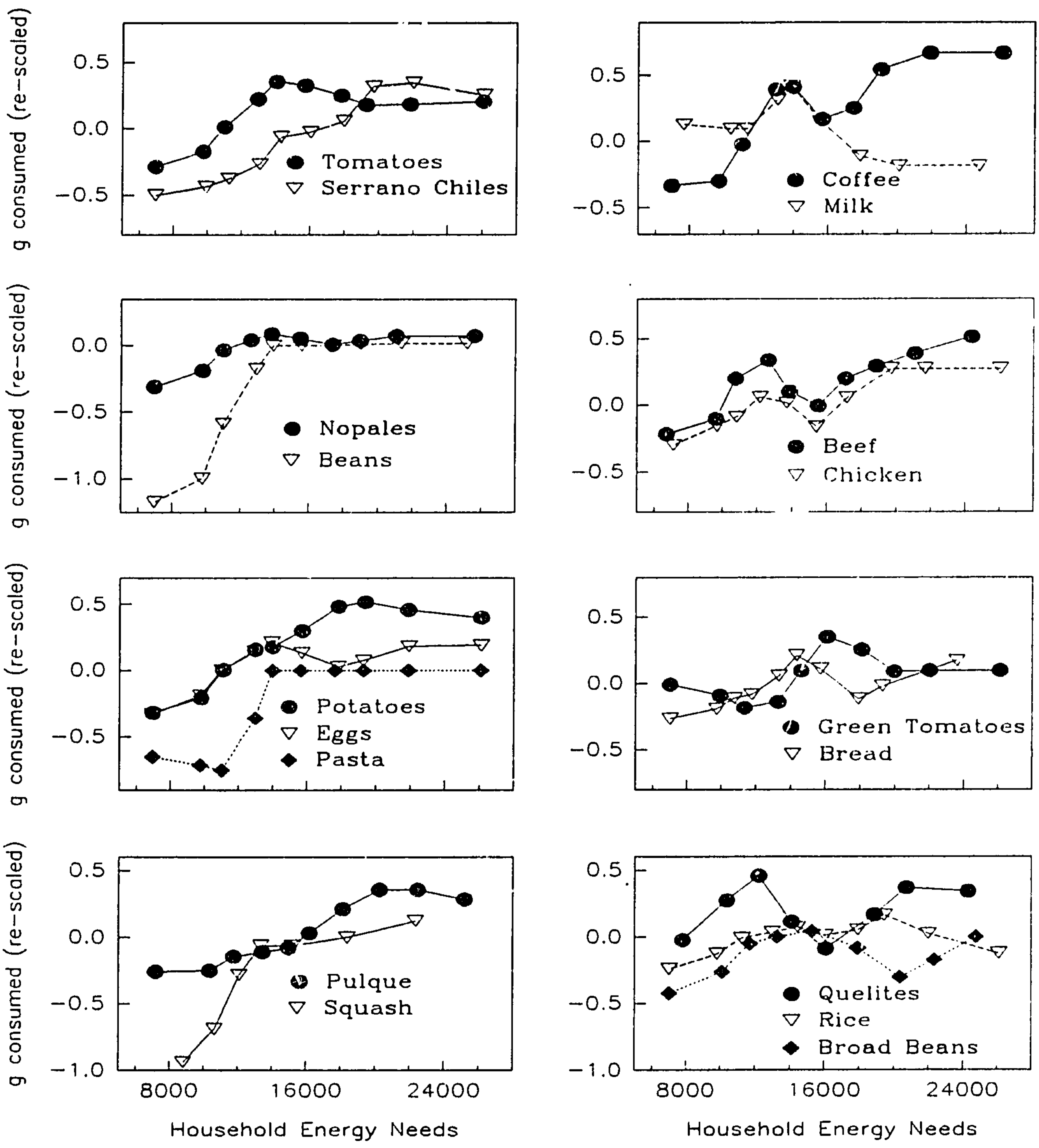

Figure 7.12: Median traces of consumption weights of 18 key foods with respect to estimated household energy needs.

food). As would be expected, household energy needs has sizeable correlations with the median weight of consumption of most foods (low correlations existing for rice, *quelites*, green tomatoes, dried broad beans, and milk). Figure 7.11 shows the smoothed medians for the consumption weights of the 18 key foods. Many of the foods show a flattening at approximately 18,000 kcal per day. This is particularly notable for tomatoes, chiles, eggs, squash, beans, potatoes, and pasta.

These results suggest that household energy needs and household material wealth affect dietary quality in very different ways in the target households. Material wealth increases dietary quality by increasing the frequency of consumption of foods such as animal products and fresh vegetables that are importance sources of nutrients in scarce supply in this population. However, with the exception of milk, which is a very important component of the preschooler's diet, material wealth does not translate into larger quantities of food. In contrast, higher household energy needs (larger household size) appears to negatively affect household dietary quality by the dilution of the household food supply. Households appear to increase the quantity of food consumed up to a point (six or eight persons). After that point, the quantity of food prepared appears to remain fairly constant, and the difference is made up with *tortillas*.

Other Social Factors and Household Dietary Quality

Household material wealth and household energy needs are the major social determinants of household dietary quality. However, several other social variables are also associated with the quality of household diet. Table 7.7 provides the correlations of selected social variables with the dietary quality variables for the total sample, and for three wealth groups (low, medium, and high). The table shows sizeable positive associations with better dietary quality for maternal and paternal education, literacy, travel from the valley, aspirations for children's schooling, and knowledge of non-valley facts (for %ANIM).

For the low wealth group, greater maternal and paternal age were associated with poorer quality diets, while parental literacy, higher education, and better maternal knowledge of facts were associated with better quality diets. For the intermediate wealth group, maternal education and literacy remained good predictors of more animal products in the diets. Parental aspirations for children's schooling also were good predictors of dietary quality. For the high wealth group, several different variables were good predictors of better dietary quality, including the appearance of the house and yard (with %ANIM), maternal and paternal education, literacy (with %ANIM), and aspirations for children's schooling (both variables).

Careful modeling showed the best additive, three variable multiple regression model for both %ANIM and %TORT to contain maternal education in addition to household energy needs and household material wealth (Table 7.8). Inclusion of this variable added 12% to the R-square for the %ANIM model (to 44%), and 6% for %TORT (to 29%). Paternal education was nearly as good a predictor as maternal education, the two variables being moderately correlated (r=0.32).

Table 7.7: Spearman's correlations for dietary quality and social variables.

	Total Sample			Lowest			Intermediate			Highest	
	N	%Anim	%Tort	N	%Anim	%Tort	N	%Anim	%Tort	N	%Anim	%Tort
Household												
Household Material Wealth	203	.47	-.37	68	.25	-.20	67	.22	-.05	68	.24	-.25
Household Energy Needs	203	-.26	.30	68	-.29	.29	67	-.22	.31	68	-.20	.24
Size of Maize Harvest (kg)	197	.08	-.11	67	-.06	.02	65	.03	-.12	65	.08	-.11
N of Chickens	203	.23	-.14	68	-.06	.03	67	.18	.00	68	.18	-.12
N of Cows	203	.18	-.05	68	.23	-.14	67	.01	.12	68	.16	-.04
Appearance of House	203	.32	-.26	68	.22	-.21	67	.18	-.23	68	.25	-.14
Appearance of Yard	203	.11	-.11	68	.10	-.07	67	-.10	-.06	68	.21	-.13
Mother												
Age	203	-.24	.24	68	-.39	.36	67	-.20	.22	68	-.12	.07
Level of Education	183	.40	-.30	62	.43	-.30	61	.25	-.16	60	.49	-.32
Able to Read or Write	198	.34	-.29	67	.21	-.33	65	.26	-.17	66	.25	-.07
Aspirations Child's School	175	.31	-.33	61	-.04	-.05	58	.31	-.34	56	.45	-.40
Aspirations Child's Occupation	197	.20	-.16	66	.06	-.09	64	.15	-.05	67	.05	-.06
Trips from Valley	196	.33	-.29	66	.12	-.09	64	.13	-.14	66	.28	-.28
Knowledge of Development Programs	197	.11	-.22	66	-.02	-.15	64	.01	-.23	67	.12	-.16
Knowledge of Non-Valley Facts	197	.26	-.15	66	.30	-.23	64	.10	.01	67	.19	-.09
Father												
Age	203	-.16	.13	68	-.42	.32	67	-.03	.00	68	-.09	[illegible]
Level of Education	147	.28	-.26	47	.09	-.11	47	.17	-.20	53	.39	-.23
Able to Read or Write	198	.34	-.23	67	.27	-.26	64	.36	-.14	68	.19	-.06
Aspirations Child's Education	173	.31	-.24	61	.23	-.10	53	.24	-.38	59	.25	-.10
Aspirations Child's Occupation	186	.18	-.17	64	.11	-.12	60	.22	-.22	62	.10	-.04
Trips from the Valley	185	.20	-.28	64	.19	-.30	59	.04	-.19	62	.17	-.28
Knowledge of Development Programs	186	.10	-.16	64	.09	-.13	60	-.02	-.16	62	.12	-.14
Knowledge of Non-Valley Facts	186	.28	-.17	64	.15	.06	60	.22	-.07	62	.30	-.26

Table 7.8: Multiple regression models predicting squared mean % of household energy from *tortillas* (%TORT²) and log mean % of household energy from animal sources (log %ANIM).

LOG % ANIMAL KCAL

	Variable	Parameter Estimate	t	prob
Model 1	Intercept	1.8821	7.48	.0001
(N=183)	HHold Energy Needs (÷ 10000)	-0.0651	-2.27	.0243
	HHold Energy Needs (÷ 1000)²	0.0016	1.92	.0560
	Household Material Wealth	0.1155	8.64	.0001
	Maternal Education	0.0871	4.75	.0001
Model 2	Intercept	1.3057	7.42	.0001
(N=157)	HHold Energy Needs (÷ 1000)	-0.0157	-2.31	.0224
	Household Material Wealth	0.1113	7.12	.0001
	Maternal Education	0.0836	4.06	.0001
	Maternal Aspirations for Children's Schooling	0.0786	1.97	.0505

Model 1 R-square = .44 Root MSE = 0.447
Model 2 R-square = .46 Root MSE = 0.460

% TORTILLA KCAL²

	Variable	Parameter Estimate	t	prob
	Intercept	4443.4948	14.66	.0001
Model 1	HHold Energy Needs (÷ 10000)	43.0239	3.07	.0001
(N=183)	Household Material Wealth	-187.9514	-5.91	.0024
	Maternal Education	-138.2941	-3.24	.0014
Model 2	Intercept	4955.9916	12.50	.0001
(N=157)	HHold Energy Needs (÷ 10000)	55.5082	3.62	.0004
	Household Material Wealth	-171.1621	-4.87	.0001
	Maternal Education	-108.0330	-2.33	.0211
	Mother's Aspirations	-263.3828	-2.93	.0039

Model 1: R-square = .29 Root MSE = 1065.3
Model 2: R-square = .37 Root MSE = 1035.5

The best four variable models contained paternal aspirations for schooling. However, paternal aspirations was a better predictor of %ANIM, while maternal aspirations were a better predictor of %TORT. The addition of maternal aspirations for schooling to the %TORT model substantially improved the R-square from 0.29 to 0.37, while the addition of parental aspirations to the %ANIM model improved the R-square from 0.46 to 0.48. The addition of interaction terms did little to improve the R-squares, although interactions were seen between maternal aspirations for schooling and maternal education (for both %ANIM and %TORT) and household material wealth (%ANIM).

These results suggest that education and parental aspirations play a role structuring household dietary quality. Education appears to affect dietary quality regardless of level of wealth. In contrast, there are indications that parental aspirations were most important when wealth and/or education permitted the translation of these aspirations into dietary behavior.

Intra-Household Variation in Dietary Quality

Table 7.9 shows the distribution of the dietary quality deviation scores for the three subject types. Consistent with results in Chapter Six, nearly all preschoolers consumed a higher proportion of energy from animal products and a lower proportion from *tortillas*. In comparison, mothers and school-aged children tended to consume more *tortillas* and less animal products.

Table 7.10 shows the Spearman correlations of the deviation scores with selected social variables. Greater relative preschooler consumption of animal products was associated with higher wealth, more cows, higher maternal education and knowledge of non-valley facts, more maternal trips from the valley, and higher parental aspirations. In contrast, none of the social variables were very good predictors of the mother and school-aged child's deviations from the household norm.

The situation for *tortilla* consumption was different from that seen for animal products, there being few sizeable correlations. For the preschooler, higher maternal education, more maternal trips from the valley, and better maternal knowledge of non-valley facts were associated with less *tortilla* consumption than the household norm.

From these results, it can be concluded that individual deviations in dietary quality from the household norm are generally not systematic. The major exception is the preschooler, who tends to receive more animal products and fewer tortillas than preschoolers and mothers. The favoring of the preschooler tends to happen in households that are wealthier, better educated, and have better access to fresh milk.

Table 7.9: Distribution of dietary quality deviation scores for preschooler, school-aged child, and mother.

	Mean	SD	Q1	Median	Q3
Preschooler (N=85)					
% Animal	4.3	3.88	1.6	3.7	5.9
% Tortilla	-14.9	10.52	-21.8	-15.4	-8.7
School-Aged Child (N=106)					
% Animal	0.6	1.95	-0.7	0.5	1.8
% Tortilla	-2.1	9.36	-10.0	-1.1	4.7
Mother (N=177)					
% Animal	-0.5	2.20	-1.5	-0.5	1.0
% Tortilla	-2.5	8.43	-8.2	-1.8	2.8

Discussion

In these rural Mexican households, diet is strongly structured by social and economic factors. The most important of these forces are household size and household economics. In much previous social science research, attention has focused on dietary energy. In this chapter we show most household energy intakes to exceed estimated energy needs. Household energy intake bears little relationship to any of the social variables. Household *energy need* shows little relationship to household *energy intake* until household needs reach approximately 20,000 kcal per day, when there is a decline in energy intake against needs. However, individual dietary intake is unrelated to household energy needs, suggesting that the apparent decline in household energy sufficiency may be an artifact.

As households become larger, and energy needs higher, consumption of maize by these households increases proportionately. However, consumption of non-maize foods fails to keep pace with maize consumption. As a result, household dietary quality deteriorates. Plots show this decline in dietary quality to continue until the household has energy needs of approximately 20,000 kcal (9 people). At this point, there is a halt (or even reversal) in the deterioration of the diet, perhaps due to additional wage-earners in the house. Data on 18 foods shows household energy needs to have little relationship to the *frequency of consumption* of most foods. As would be expected, the *weight* of the food typically consumed was often associated with household energy needs. However, several foods showed little relationship between the weight of the food consumed and the size of the household. Also, plots showed many of these foods to have a characteristic flattening at approximately 18,000 kcal per day, the weight of the food ceasing to increase as energy needs increase. These results show large household size to affect dietary quality negatively by diluting the household supply of non-maize foods.
Household material wealth is the best social predictor of household and individual dietary quality, and household energy needs is second best. Correlation analyses show no relationship

Table 7.10: Spearman's correlations of social variables with dietary quality deviation scores for preschooler, school-aged child, and mother.

	Preschooler			School-Aged Child			Mother		
	N	Anim	Tort	N	Anim	Tort	N	Anim	Tort
Household									
Household Material Wealth	85	.23†	-.21*	106	.06	-.18*	165	-.08	-.11
Household Energy Needs	85	-.19*	.18	106	-.10	.10	165	.05	-.11
Size of Maize Harvest (kg)	81	.02	.08	100	-.09	.11	156	-.12	-.05
N of Chickens	85	.25†	-.09	106	.03	-.05	165	-.09	.01
N of Cows	85	.25†	-.12	106	-.21†	.21†	165	-.11	.01
Appearance of House	85	.23†	-.15	106	.03	.15	165	-.08	.02
Appearance of Yard	85	.17	-.13	106	.08	-.18	165	-.08	.02
Mother									
Age	85	.05	.08	106	-.00	-.03	165	.09	-.15
Level of Education	73	.27†	-.38 ‖	103	.02	-.08	152	-.15	.07
Able to Read or Write	83	.29‡	-.28†	105	.02	-.08	163	-.11	.07
Aspirations Child's Schooling	73	.28†	-.23*	97	-.14	-.05	147	-.11	.01
Aspirations Child's Occupn.	83	.24†	-.21*	105	-.07	.03	163	.01	-.03
Trips from Valley	77	.10	-.18	100	-.12	.03	152	-.25‡	.12
Knowledge Devpt. Programs	83	-.01	-.08	105	-.08	-.05	163	-.06	.05
Knowledge Non-Valley Facts	83	.34§	-.37§	105	.12	-.21†	163	-.07	-.02
Father									
Age	85	-.01	-.07	106	.17	-.17	165	.19†	-.28‖
Level of Education	61	.23*	-.21*	89	-.04	-.07	126	-.28§	.11
Able to Read or Write	77	.16	-.14	101	-.12	-.08	153	-.16†	.14
Aspirations Child's Schooling	72	.24†	-.20*	92	-.06	-.17	141	-.15*	.05
Aspirations Child's Occupn.	77	.14	-.11	101	-.00	.03	153	-.00	-.03
Trips from the Valley	77	.10	-.18	100	-.12	.19	152	-.25§	.12
Knowledge Devpt. Programs	77	-.04	-.07	101	-.18*	-.12	153	-.23§	.15
Knowledge Non-Valley Facts	77	.10	-.04	101	.00	.06	153	-.09	-.00

* $p<0.01$ † $p<0.005$ ‡ $p<0.001$ § $p<0.0005$ ‖ $p<0.0001$.

between household material wealth and household energy needs. Among the wealthiest households, there was larger variation in dietary quality than for poorer households, indicating the greater options that richer households have. Between household energy needs and household material wealth, 32% of the variance in the proportion of household energy from animal sources can be explained, and 23% of the variance the percent of energy from tortillas. These results show dietary quality to be highly structured by the constraints of household size and economic resources. The lack of interactions between wealth and energy needs show even the diets of the wealthiest to suffer as a result of larger household sizes. Data on 18 key foods shows household material wealth to have its primary effect through more frequent consumption of non-maize foods rather than by consumption of larger quantities of the foods. As many foods must be purchased in town or on market days, the frequency of consumption of many foods is likely to be related to access to transportation, and food storage. Therefore, the affect of household material wealth on diet may be due to reduced access to food in addition to reduced purchasing power.

A large number of other social variables are correlated with the household dietary quality variables. Regression analyses show the best predictors, in combination with household energy needs and material wealth, to be the level of education of the parents (particularly the mother), and the expressed parental aspirations for the degree of schooling of their children. Multiple regression models containing material wealth, energy needs, maternal education, and maternal aspirations for children's schooling explain 46% of variance in the percent of energy from animal sources and 37% of variance in the proportion of energy from tortillas. Interactions with level of education and material wealth suggest that parental aspirations may be most important when knowledge and/or economic resources permit the translation of these desires into dietary behavior. Also, this extraordinarily large proportion of the variance explained shows dietary quality to be the quintessential social outcome, and suggests that dietary quality in other societies may be as readily modelled.

In these households, most food is consumed within the confines of the household. Therefore, it is not surprising that the best predictor of the quality of the individual's diet is the dietary quality of the household. Nearly 70% of the variance in the dietary quality of the preschooler and school-aged child is accounted for by variation in household dietary quality. Because of this, the dietary quality of individuals in the same household is also very similar. All correlations. The strong similarity among individual measures of dietary quality have several implications. First, the role of intra-household variation in this population appears to be minor: individual diets are a close reflection of household diets. Second, high correlations among individual measures make it difficult in practice to distinguish between the effects of maternal intake vs infant or preschooler intake. Nevertheless, socially-patterned intra-household variation in dietary quality occurs for at least one type of individual in these households: the preschooler. The preschooler tends to consume a better quality diet than the rest of the household. In addition, the wealthier the household, and the better educated and more knowledgeable the mother, the better the preschooler diet is with respect to the diet of the household as a whole. This result suggests that the effects of wealth and education on diet are most significant for young children: the very age-group that suffers most from growth stunting.

Policy Implications

- Insufficient dietary energy does not appear to be the most important nutritional problem in this population. However, many households do not produce enough maize to support them throughout the year. Nevertheless, these households appear to be able to use their scarce resources to acquire enough of their staple food, maize, to meet household demand. In contrast, dietary quality is clearly affected adversely by insufficient resources and food policies should therefore focus on dietary quality. In those cases where insufficient dietary energy is a problem, dietary quality will also be a problem.

- Larger households have poorer dietary quality. Any beneficial effects of larger households (i.e., additional wage-earners) is more than offset by prior deterioration in dietary quality. Reducing the birth rate would have a beneficial effect on the dietary quality of most households, particularly as most households in these communities will someday be large (Chapter Ten).

- Higher household material wealth is associated with more frequent consumption of several important foods, but not with the quantity of the food consumed by the household (except in the important case of milk which is primarily fed to young children). To restate, *wealthier households do not consume larger portions of most foods*. As all households, regardless of wealth, suffer from the dilution of the household food supply, this suggests that policies aimed at promoting the feeding of a certain quantity of non-maize foods to children might be beneficial for better-off households. Because local stores seldom stock perishable food items, increased frequency of consumption of some non-maize foods may be due in part to increased access to food markets and improved food storage (refrigeration). Also, home-production of some foods may be discouraged by food storage problems. Therefore, the promotion of refrigeration via help in obtaining or saving cash for the purchase of refrigerators would likely be beneficial.

- Maize production shows little relationship to dietary quality. Although most households are engaged in some maize agriculture and most are maize independent, most non-maize foods are purchased [1].

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Chapter Eight.
Anemias, Iron, Vitamin B_{12} and Folate Status

Micronutrient Measures in Mexico

Because of the emphasis on marginal energy deficiency in the CRSP, there was initially less interest in the prevalence, causes and consequences of micronutrient deficiencies. Hemoglobin and serum ferritin measures were incorporated into the original study design to control for any effects of iron deficiency anemia on functional outcomes such as growth, behavior and birth weight. In the Mexico CRSP, however, we measured hematological parameters with a Coulter counter. Preliminary analyses of those data revealed that: anemia was very prevalent in all groups of target subjects; many low hemoglobin values were unaccompanied by low ferritin values; and there was a tendency to macrocytosis in the population. The latter two findings led us to analyze samples remaining, after field work had ended, for plasma vitamin B_{12} and folate, and breast milk vitamin B_{12}.

Anemia has been recognized as a public health concern in Mexico since the early 1960s. The prevalence of anemia in Latin American children has been estimated at 26%. Past research at INNSZ has identified hookworm (in tropical lowlands) and dietary iron inadequacy as probable causes [1,2]. Children require iron, folate, and B_{12} for growth and optimal accumulation of stores in addition to needs for maintenance. Although the iron intakes of our Mexican CRSP target subjects were surprisingly high, the bioavailability of this iron, furnished in large measure by *tortillas* and beans, was suspected to be poor due to the presence of large amounts of phytate and fiber, and low amounts of ascorbic acid (Chapter Six). Neither folate nor B_{12} deficiency anemia has been thought to be a serious public health problem in Mexico, but previous work on the prevalence of vitamin B_{12} deficiency needs to be re-evaluated using newer radioassay techniques that discriminate between the active vitamin and other cobalamins [3].

Associations between diet and anemia have rarely been identified in field studies, because of the difficulties of measuring intake over a sufficiently long period, accounting for factors that affect the bioavailability of micronutrients from the diet, and controlling for other factors that may cause anemia. Because the CRSP was a longitudinal study, the repeated collection of dietary measures from the same individuals contributed to a good estimation of typical intakes. Correction for bioavailability was attempted by creating variables that model the interactions among dietary nutrients (Chapters Three and Six). Finally, the CRSP has a wealth of information on other factors that may affect anemia, iron, B_{12} and folate status, such as physiological status of women, parity and morbidity. With these issues in mind the following analyses examine the prevalence and predictors of anemia, iron, B_{12} and folate status in the target subjects. No previous community-based study has explored the relationships among dietary patterns, other risk factors and iron-deficiency anemia in a developing country. A more detailed description of the methods and results has been published elsewhere [4,5,6].

Collection and Analysis of Blood and Milk

Clinic visits for blood drawing were scheduled at the end of one year of study for NPNL women and men, at 5 and 8 mo of pregnancy, and at 1, 3 and 6 mo of lactation. For preschoolers and schoolers, blood was drawn once at the end of the study and mothers were requested to bring children only if healthy. All individuals were transported to the Solís clinic early in the morning, in the fasted state.

Fasting venous blood samples were drawn with EDTA as the anticoagulant. Hematological analyses were made with a Coulter counter, and plasma ferritin was analyzed in duplicate by radioimmunoassay. WBC counts (<15000 cells per mm^3) were used to screen for inclusion of healthy individuals.

Folate and B_{12} analyses were performed by radioassay with purified hog intrinsic factor and bovine milk folate binding protein. All of the women's and children's samples were analyzed if sufficient plasma was available. Adult male plasma samples were chosen for folate and B_{12} analyses based upon MCV values that suggested the possibility of deficiencies of these vitamins (MCV ≥ 100 n=11, MCV <100 n=12).

During their scheduled visits to the clinic a breastmilk sample was requested from lactating women at both the beginning and end of a feeding. Vitamin B_{12} content was measured by radioassay following digestion of the sample with papain to release the bound B_{12} from R-binder [7].

Anthropometric measurements (weight, height) were taken within 31 d of blood drawing for NPNL women, and men and children. In addition to the weekly morbidity data, estimates of parasite load were obtained from microscopic examination of 5 fecal samples (range 2-10) for women and 3 for men and children (range 1-4). Subjects were classified as "positive" if eggs, cysts, or worms were found in any fecal sample.

Associations between indices were examined using Spearman's rank-order correlations. The Wilcoxon 2-Sample Test was used to examine differences between subjects with sufficient vs. deficient biochemical values. Seasonality in diet was examined using paired t-tests or signed rank tests depending upon difference distributions.

Data are presented first for adults, then for children.

Adult Women and Men

Of the 226 women and 142 men who participated in the CRSP, blood was drawn from 187 women and 72 men, self-reported as healthy. Women were non-pregnant (enrolled because they were the mothers of target children), pregnant when enrolled, and/or became pregnant then lactating during the investigation.

Prevalence of Anemia and Nutrient Deficiencies in Adults

Anemia was defined as low hemoglobin with an altitude correction of +13 g/L [8] assuming an average altitude of 2500 m. Cut-offs were therefore <148 g/L for adult men, <133 for NPNL and L women and <123 for P women in the third trimester. Iron deficiency was defined as plasma ferritin less than 12 ng/mL, low folate as <6.1 nmol/L (2.7 ng/mL) and low plasma B_{12} as <103 pmol/L (<140 pg/mL) except for pregnant women (<74 pmol/L, <100 pg/mL).

In cross-sectional analyses, hemoglobin was lower in pregnant women as expected (Table 8.1). Although the average value is comparable to that of unsupplemented women in industrialized countries, it is actually raised because of the altitude in Solís. The average value for plasma ferritin is deficient in P women. The considerably higher values in men compared to women reflect their greater iron stores. Plasma folate and B_{12} are similar across all groups. The large standard deviation of mean plasma B_{12} in pregnancy may have been caused by B_{12} injections which are said to be taken by some pregnant individuals in the population. Mean values for folate and B_{12} in men may be lower than the population average as the men's samples were selected for analysis on the basis of high mean cell volumes (MCV)s, a sign of B_{12} or folate deficiency. The mean MCV of 97.6 fL among adult men is high compared to the average of 89.2 fL for U.S. men of this age. The mean MCV of NPNL women is also higher compared to that of U.S. women. Parity is high compared to the U.S. but typical for the Solís Valley.

Anemia was highly prevalent, occurring in one third of the men to over half of the NPNL women (Figure 8.1). Pregnant women had the most iron deficiency (65%), and adult men the least (4%). About one third of NPNL and L women were iron deficient. No subject had low plasma folate. Low plasma B_{12} levels were most frequent among L (30%) and least frequent among P women (15%); 19% of NPNL women had low values. The prevalence of B_{12} deficiency among men is not shown in Figure 8.1 because the samples were not chosen randomly. However, low plasma B_{12} was found in 6/23 (26%) of their samples.

A longitudinal subsample (n=49) was created composed of women who had blood samples taken in both pregnancy and lactation, in order to examine the changes that occur during pregnancy and lactation. Because there were no significant differences between second and third trimester values for hematology values or ferritin, women with values recorded in either of these trimesters were combined in one group with measurements made at 7 mo +/- 68 d of pregnancy. Samples from lactating women represent 7 mo +/- 60 d of breastfeeding. Values in this subsample are very similar to those for the cross-sectional groups except for a lower mean

Table 8.1: Description of adult's plasma values.

	WOMEN						MEN	
	NPNL		Pregnant		Lactating			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hemoglobin (g/L) (n=71-91)	130	13	127	14	133	11	154	11
Ferritin (ug/L) (n=59-74)	20	3	10	3	17	3	95	2
Folate (nmol/mL) (n=20-34)	25	9	25	11	25	16	27	9
B_{12} (pmol/L) 186 (n=20-34)	108	228	451	181	152	224	183	
MCV (fL) (n=71-91)	94	5	93	8	94	5	98	6
Age (y) (n=71-93)	35	7	30	7	31	7	40	8
Parity (n=70-88)	7.8	3	6.1	3	6.5	3		

plasma B_{12} in P women (228 pmol/L); the difference was caused by one exceptionally high value in the cross-sectional sample. In the longitudinal sample anemia was again found in roughly one-third of the women (Figure 8.2). Iron deficiency is most prevalent in pregnancy with a substantial portion, but not all, of the women rebuilding stores during lactation. On the other hand, eight of the 49 women in this sample were not anemic during pregnancy but became anemic during lactation, with hemoglobin levels falling in all but one of the eight. Six of these women with ferritin showed an increase in plasma ferritin from deficient (2-12 ug/L) to sufficient levels (18-28 ug/L), indicating that the onset of anemia in lactation was not due to iron deficiency. Low plasma B_{12} levels were more frequent in lactation (30%) than in pregnancy (19%).

The analyses indicate that anemia in these adults is caused by several nutrient deficiencies. Iron deficiency (low ferritin) occurred in only 4% of the anemic men, 38 and 40% of anemic NPNL and L women and 67% of anemic P women. Plasma ferritin levels were not significantly

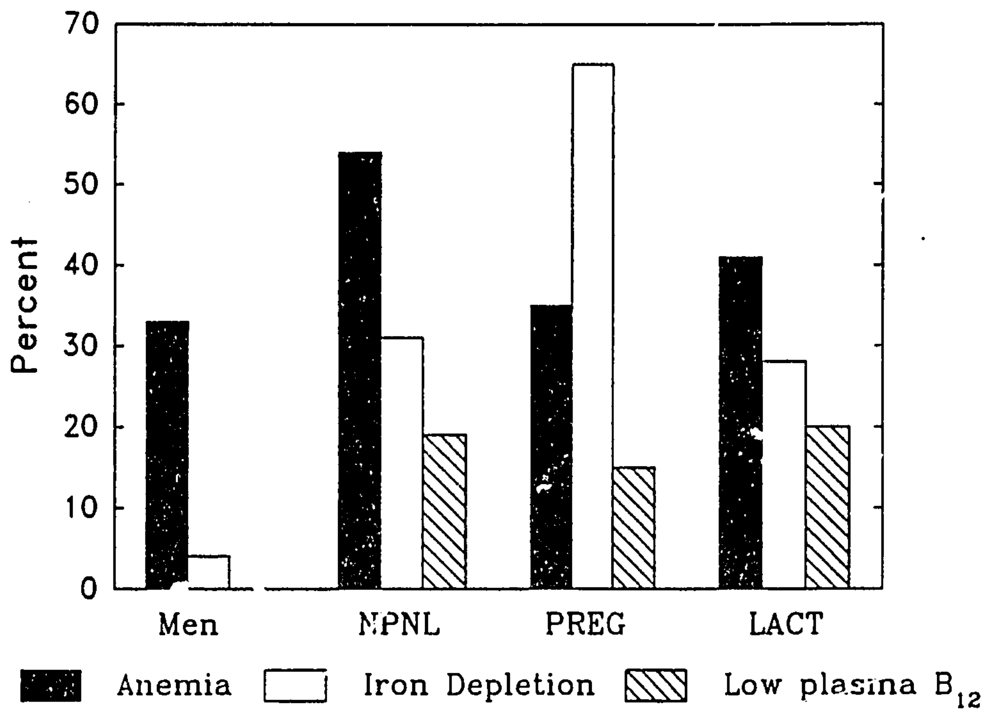

Figure 8.1: Frequency of anemia and nutritional deficiencies in adults.

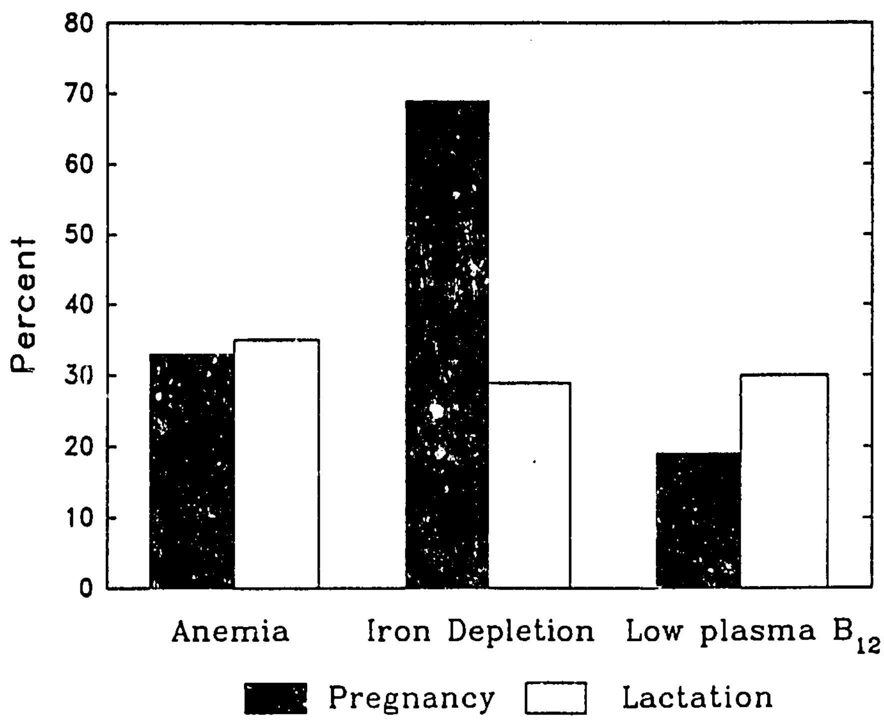

Figure 8.2: Frequency of anemia and nutritional deficiencies during pregnancy and lactation: longitudinal sample.

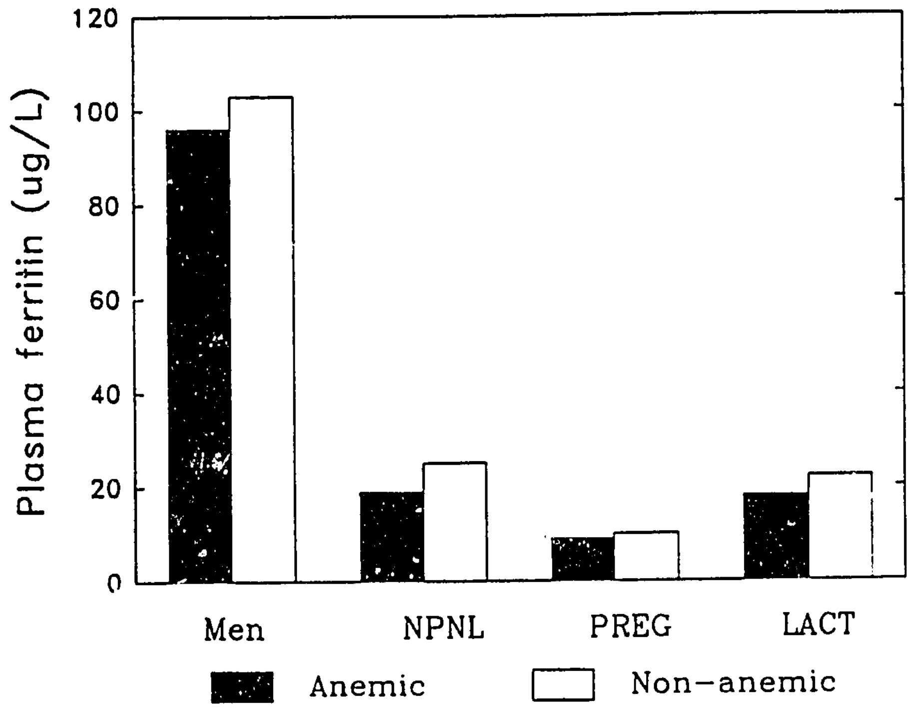

Figure 8.3: Mean plasma ferritin: anemic and non-anemic adults.

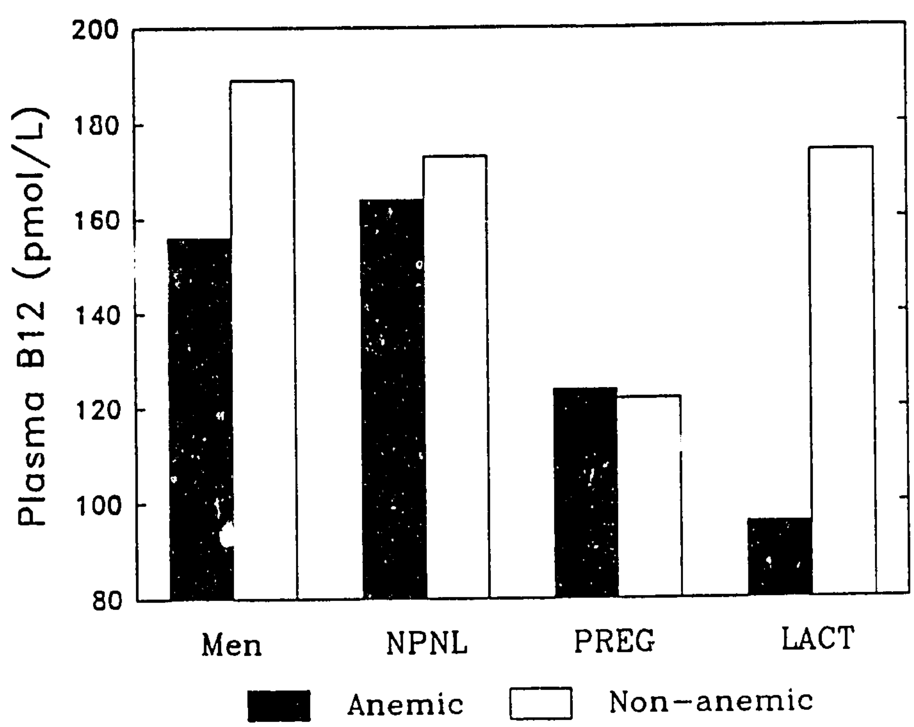

Figure 8.4: Mean plasma B_{12}: anemic and non-anemic adults.

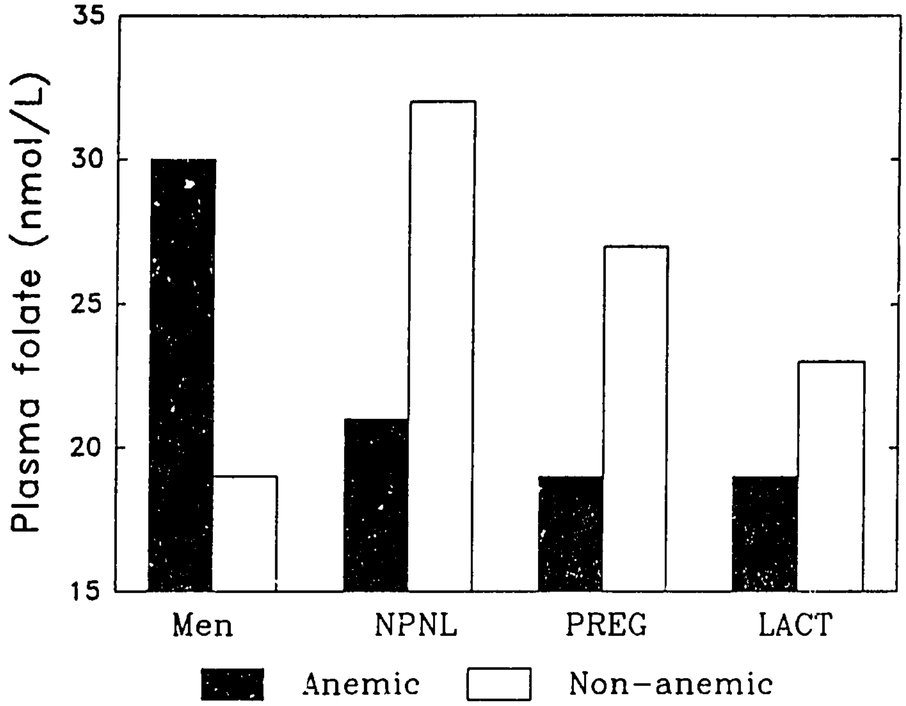

Figure 8.5: Mean plasma folate: anemic and non-anemic adults.

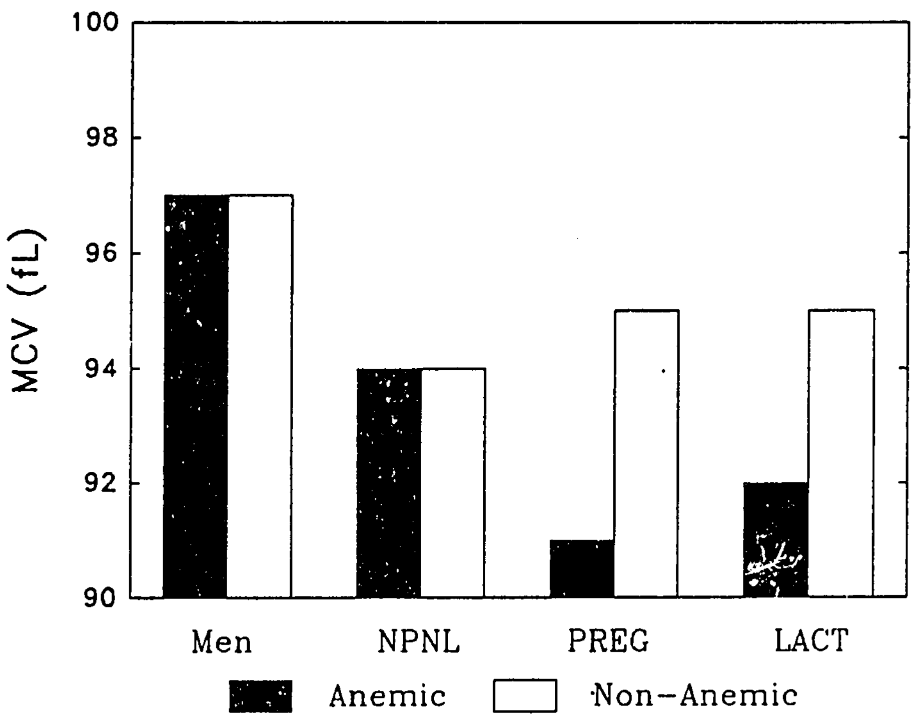

Figure 8.6: Mean mean corpuscular volume: anemic and non-anemic adults.

different between anemic and non-anemic adults (Figure 8.3). Plasma B_{12} was significantly lower (Figure 8.4) and the median value was deficient in lactating anemic vs. non-anemic women (median=96 pmol/L vs. 174 pmol/L, P = 0.02). Plasma folate was significantly lower in anemic NPNL women although no values were deficient (Figure 8.5) . Furthermore, low mean corpuscular volume (Figure 8.6) is not useful for identifying anemia in this population with multiple nutrient deficiencies. There were no low MCV values among NPNL or L women or men, and only 6% in P women.

Relationships Among Anemia, Plasma Nutrient Levels and Food Intake in Adults

Subjects had a minimum of 7 days of food intake data in these analyses; the average number of records for NPNL women was 17, for men 20. Available iron, the phytate:iron molar ratio, and the phytate:ascorbic acid molar ratio were calculated as indicators of iron bioavailability.

The dietary variables for women and men in this sample are summarized in Table 8.2. For exploring relationships between diet and nutritional outcomes, analyses were restricted to men and NPNL women to avoid the variable effects of pregnancy and lactation on food intake, anemia and plasma nutrient levels. Average energy and protein intakes are adequate, and phytate intakes are much higher than the average of 750 mg/day for an omnivorous man in the U.S. or the U.K. Although iron intakes are high, the amount of more absorbable heme iron is very low. U.S. diets contain half as much total iron of which 10% is heme. Estimated average available iron intakes by the men meet the 1 mg/day recommendation, but NPNL women's intakes are inadequate to cover average daily losses of 1.5 mg.

Relationships between diet in NPNL women and anemia or plasma nutrient levels are shown in Table 8.3. Anemic women consume diets containing significantly less heme iron, but significantly higher phytate:iron and phytate:ascorbic acid ratios ($p<0.10$, one-tailed). Among men diet was not associated with anemia. No dietary variables were associated with iron deficiency (low ferritin levels) in NPNL women. Analyses of the relationship between iron status and diet in adult men were not undertaken because there were few cases of iron deficiency (2/51).

In this community, individuals whose diet is based more on *tortillas* and less on animal products generally consume more total energy, protein and fiber. This may be attributable to the lower digestibility of diets high in *tortillas*. Reflecting their higher intake of plant products (Table 8.4), NPNL women with low plasma B_{12} consumed more energy, protein and fiber than those women who were B_{12} sufficient. Low plasma B_{12} in men occurs when their diets are lower in animal products (Table 8.5).

Table 8.2: Dietary intakes of NPNL women and men.

	WOMEN (NPNL)		MEN	
	Mean	SD	Mean	SD
Energy (kcal)	2377	555	3078	792
Protein (g)	69	16	84	19
Fiber (g)	31	10	37	11
Animal (kcal)	160	132	192	131
Plant (kcal)	2217	567	2886	813
Tortilla (kcal)	1469	498	1823	614
Legumes (kcal)	132	85	154	94
Pulque (kcal)	144	184	446	489
Meat (kcal)	68	49	84	73
Dairy (kcal)	50	82	45	73
Iron (mg)	27	7	33	9
Ascorbic (mg)	49	32	93	68
Heme Fe (mg)	0.53	0.56	0.47	0.49
Non-heme Fe (mg)	26	7	33	9
Avail. Fe (mg)	1.3	0.4	1.2	0.4
Phytate (mg)	4095	1351	5033	1641
Phytate:Iron	36	7	34	7
Phyt.:Ascorbic	287	193	280	222

Changes by Season in Adults

Season had a significant effect on hemoglobin levels in all cross-sectional groups (Figure 8.7). Seasons were defined as the post maize harvest, winter period and a pre-harvest time when up to 32% of families (vs. 0% in December and January) must purchase maize for *tortillas*. However, in the pre-harvest season there is a greater availability of home-produced or gathered seasonal plants, squash, broad beans, *quelites* (wild greens) and *tunas* (fruit of the nopal cactus). All adult groups had lower hemoglobin levels pre-harvest. At this time MCV values were significantly higher (median 98 fL vs 92 fL post-harvest, P = 0.001) as is plasma ferritin (median 17 ng/dL vs. 9 ng/dL, P = 0.02). The lower hemoglobin accompanied by high MCV and higher ferritin levels suggests an inability to use iron stores due to vitamin B_{12} deficiency.

Table 8.3: Dietary intake and anemia in NPNL women.

	ANEMIC (n=38)			NON-ANEMIC (n=33)		
	Med	Q1	Q3	Med	Q1	Q3
Energy (kcal)	2373	2018	2771	2256	2013	2668
Protein (g)	69	58	80	63	57	80
Fiber (g)	30	26	39	30	24	35
Animal (kcal)	119	85	169	146	74	241
Plant (kcal)	2204	1917	2669	2177	1780	2880
Iron (mg)	26	23	32	25	20	30
Ascorbic (mg)	35	26	58	40	27	77
Heme Fe (mg)*	0.28	0.13	0.53	0.51	0.12	1.00
Non-heme Fe (mg)	25	22	32	25	20	.29
Avail. Fe (mg)	1.2	1.0	1.4	1.1	1.0	1.7
Phytate (mg)	4130	3360	4954	3931	3009	4608
Phytate:Iron†	38	34	42	35	30	40
Phyt.:Ascorbic*	280	169	426	213	124	322

* $p<0.10$, † $p<0.05$, Wilcoxon rank-sum test, one-tailed

Table 8.4: Dietary intakes and vitamin B_{12} status of women and men.

	WOMEN (NPNL)		MEN	
	Low B_{12} n=4	Adeq. B_{12} n=17	Low B_{12} n=6	Adeq. B_{12} n=17
Energy (kcal)	2909	2137	2769	3100
Protein (g)	86	60	78	87
Fiber (g)	44	29	40	37
Animal (kcal)	133	91	106	187
Plant (kcal)	2776	2014	2692	2887
Tortilla (kcal)	1981	1477	2019	1957
Meat (g)	29.6	37.4	25.7	57.4

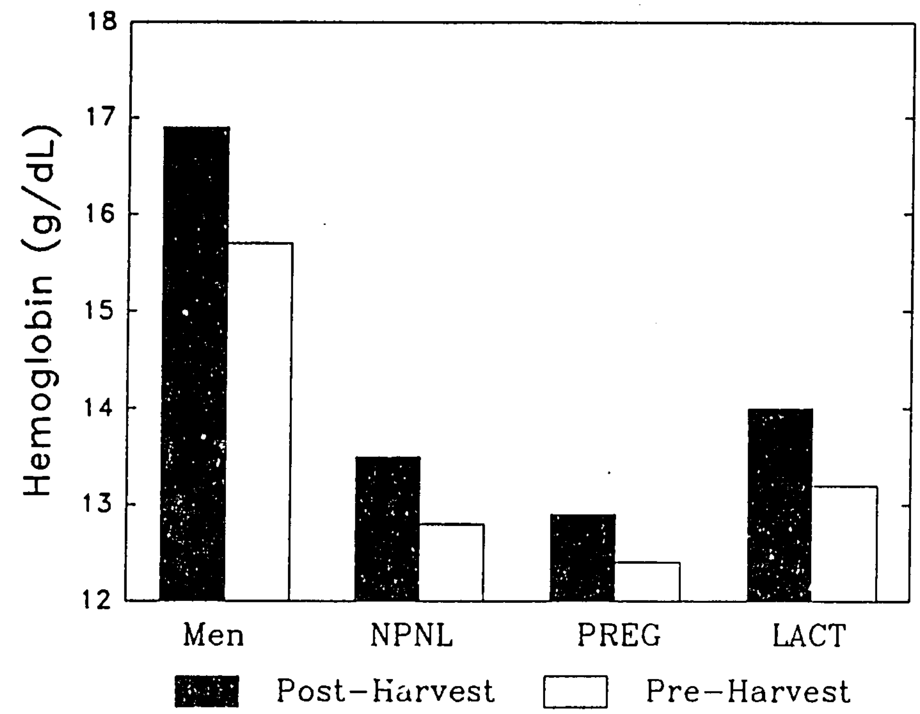

Figure 8.7: Effect of season on hemoglobin levels; median Hg (g/dL); Post-harvest = November-May, Pre-harvest = June-October.

These seasonal changes in nutritional status may be explained by seasonal changes in food intake although the actual foods involved cannot be determined (Table 8.5). Analysis is restricted to NPNL women and men who had at least 5 diet records in each season. Both men and NPNL women consumed less energy, protein, phytate, *tortillas,* meat (and presumably vitamin B_{12}), *pulque,* heme iron and available iron in the pre-harvest period. Women also consumed significantly less legumes and total iron. However, the phytate:iron and phytate:ascorbic acid ratios were lower pre-harvest for both men and women due to the fall in *tortilla* intake. No differences in ascorbic acid intakes were observed despite the presumed greater availability of fruits and vegetables during the growing season; salsa prepared from fresh tomatoes and peppers is consumed year-round and, as noted, more *pulque* is drunk in the winter. Although summer rains presumably improve grazing for dairy cows, there was no increased dairy product consumption during this time.

Relationships With Morbidity, Parasites, Anthropometry in Adults

There were no significant associations between the reported percent days ill and either anemia or nutrient deficiency. However, the incidence of adult illness was very low; 32/72 men and 21/71 women reported no illness at all during the study period. Infestation with endemic parasites, including *Entamoeba histolytica, Giardia lamblia* and *Ascaris lumbricoides*, was not

Table 8.5: Seasonality in mean daily diet intake among NPNL women and men.

	WOMEN (N=51)				MEN (n=43)			
	Post-Harvest		Pre-Harvest		Post-Harvest		Pre-Harvest	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy (kcal)	2498	647	2336	538	3148	812*	2962	716
Protein (g)	73	19	66	15	87	21*	81	19
Fiber (g)	33	11	31	10	38	13	37	14
Animal (kcal)	179	159	147	136	213	157*	185	148
Plant (kcal)	2318	656	2188	558	2934	838*	2776	760
Tortilla (kcal)	1555	567	1463	510	1870	648*	1760	671
Legumes (kcal)	154	108	120	100	169	126	142	112
Pulque (kcal)	149	176	124	183	452	431*	381	445
Meat (kcal)	77	57	58	52	87	68*	63	57
Dairy (kcal)	48	90	54	98	46	81	62	101
Iron (mg)	28	9	26	7	34	10	32	9
Ascorbic (mg)	49	34	50	31	90	61	90	64
Heme Fe (mg)	0.70	0.88	0.47	0.82	0.57	0.75*	0.37	0.42
Non-heme Fe (mg)	28	8	26	7	34	10	32	10
Avail. Fe (mg)	1.4	0.5	1.2	0.4	1.2	0.4*	1.1	0.3
Phytate (mg)	4372	1550	4017	1358	5218	1795	4814	1782
Phytate:Iron	36	7	35	8	35	7	33	8
Phyt.:Ascorbic	318	252	252	171	287	243	282	258

* $p < 0.10$

associated with anemia or nutrient deficiency. Women were more likely to test positive for evidence of parasite infestation though this may be the result of more frequent testing. Non-anemic men were more likely to be free of parasites than those who were anemic but the difference is not statistically significant.

Non-anemic women were substantially heavier (57.8 kg vs 64.1 kg, p=0.02) and had a higher weight-for-height (0.38 vs 0.43, p=0.03) than anemic NPNL women. There was no association between height and anemia in either men or women. Anemic men were older than their healthy peers, but their anthropometric measures were similar.

Deficient Levels of Vitamin B_{12} in Breast Milk.

The B_{12} content of anemic women's milk was lower than that of non-anemic women (mean 285 pmol/L, n=14, vs. 418 pmol/L, n=28, p = 0.04). In the case of 16 women with B_{12} measures in milk and in plasma during pregnancy and lactation, levels of plasma B_{12} were correlated during pregnancy and lactation (r = 0.53, p = 0.04) and plasma B_{12} during lactation was correlated with milk B_{12} (r=0.48, p=0.06). There was no statistically significant difference in milk B_{12} level based upon low vs. adequate plasma B_{12}. In 31/50 samples milk B_{12} concentrations were <362 pmol/L (<491 pg/mL), a level judged to be inadequate as below this there is increased urinary methylmalonic acid excretion in infants [9], a sign of B_{12} deficiency.

Preschoolers and Schoolers

Blood samples were drawn from 63 of the 110 target preschoolers. Of the 130 target schoolers, blood samples were taken from 93, 43 boys and 50 girls. There were no significant differences between the sampled and unsampled groups based on age at entry in the study, anthropometry, family socioeconomic status, number of people in the household, or education levels of either parent.

Prevalence of Anemia and Nutrient Deficiencies in Children

Because of the altitude correction, anemia was defined as < 125 g/L and hematocrit <38% for preschoolers and hemoglobin < 129 g/L or hematocrit <39% for schoolers. Iron deficiency was defined as plasma ferritin less than 12 ng/mL. Folate values less than 6.1 nmol/L (2.7 ng/mL) were considered low based on the manufacturer's expected values from a study of 285 diagnosed adult patient sample Low plasma B_{12} was defined as < 103 pmol/L (140 pg/mL) (manufacturer's expected values from 309 diagnosed adult samples).

Table 8.6 presents data on the hematological and plasma nutrient levels of preschoolers. Hemoglobin levels are low for this altitude being similar to those of U.S. children living at sea level, but hematocrit is higher as expected. This highlights a discrepancy encountered in the use

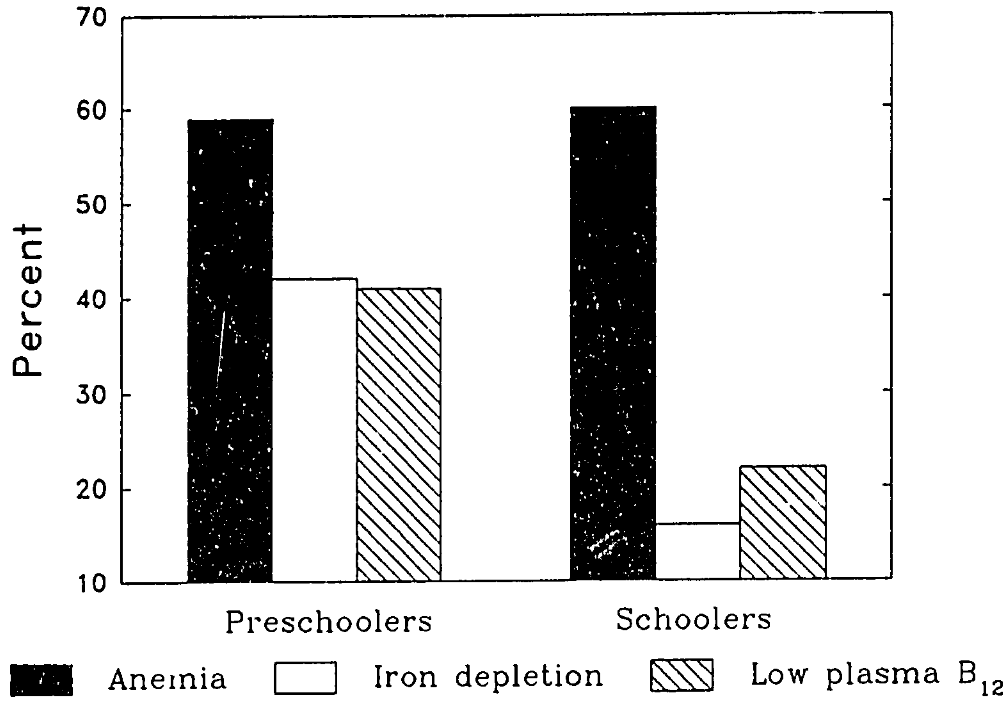

Figure 8.8: Frequency of anemia and nutritional deficiencies in preschoolers and school-aged children.

of anemia cutoffs based on either hemoglobin or hematocrit. The frequency of anemia based upon the CDC hemoglobin cut-off adjusted for altitude is 80%, while based on hematocrit, it is 58%. Figure 8.8 presents the frequency of anemia (based on low hemoglobin and hematocrit) and risk of deficiency. The average plasma ferritin level of 13 ug/L is lower than the mean of 30 ug/L reported for healthy, non-anemic U.S. children. Plasma folate and B_{12} are lower than the levels reported for Solís adults but are adequate on average. Low plasma ferritin (42%) and B_{12} (41% of children) occurred frequently, but no child had a low plasma folate level. MCV levels are higher than medians of 80.9 and 81.5 fL reported for U.S. boys and girls aged 3-5 years. There were some cases of low MCV as well as cases of abnormally high MCV.

Some of the blood indices were significantly correlated with each other. Hemoglobin was correlated with RBC counts in both preschoolers ($r=0.39$, $p<0.003$) and schoolers ($r=0.77$, $p<0.001$), and with vitamin B_{12} ($r=0.23$, $p<0.07$), ferritin ($r=0.19$, $p<0.09$) and MCV ($r=0.19$, $p<0.07$) in schoolers. In preschoolers plasma ferritin was associated negatively with RBC and WBC counts ($r=-0.34$ and -0.28, $p<0.05$) and positively with MCV ($r=0.26$, $p<0.07$) and plasma folate $r=0.39$, $p<0.04$). Among schoolers, as well as its correlation with hemoglobin, ferritin is associated with RBC and WBC counts ($r=0.19$, $p<0.09$ and $r=0.21$, $p<0.06$). Plasma B_{12} is positively associated with RBC counts ($r=0.30$, $p<0.02$). Taken together these correlations suggest that hemoglobin levels are more dependent on vitamin B_{12} status in preschoolers, in whom deficiency of this vitamin is more frequent, based on the negative association between ferritin and RBC counts; in vitamin B_{12} deficiency ferritin will be

Table 8.6: Description of children's plasma values.

	PRESCHOOLERS			SCHOOLERS		
	Mean	SD	N	Mean	SD	N
Hemoglobin (g/L)	115	12	61	125	10	93
Ferritin (ug/L)	13	2	54	20	2	80
Folate (nmol/L)	18	7	32	18	7	68
B_{12} (pmol/L)	130	91	32	152	70	68
MCV (fL)	86	7	61	90	5	93
Age	31.6 mo	2.4	63	8.7 y	0.5	94
Birth Order	5	3	63	4	2	93

higher and RBC counts lower because of insufficient B_{12} for erythropoiesis. In schoolers anemia is predicted by both iron stores and vitamin B_{12} status.

As with preschoolers, anemia is frequent in this sample of schoolers (Figure 8.8). The hemoglobin and hematocrit levels of schoolers (Table 8.6) are slightly lower than those of U.S. children at sea level. Plasma ferritin is slightly higher than in the younger children and the risk of iron deficiency is lower in this age group. Median ferritin of Mexican-Americans aged 5-10 years in the HHANES was 25.1 ug/L. Plasma folate is adequate. Plasma B_{12} is higher than in preschoolers on average, but 22% of schoolers have levels suggestive of inadequacy. MCV is higher than the median value of 82.6 reported for U.S. children.

Relationship Between Anemia, Plasma Nutrient Levels and Diet in Children

Daily records of preschoolers before the reported date of weaning were excluded. Children had a minimum of 7 records; the average number of records for preschoolers was 21 (range 10-34), for schoolers 16 (range 8-26).

Dietary intakes of children are presented in Table 8.7. As for the Solís children in general, average energy intakes are adequate, and protein intakes are more than adequate even adjusting for lower protein digestibility of a high maize diet. Preschoolers consumed 74%, and schoolers 83%, of protein from plant sources. The nutrient needs of the schoolers, compared to preschoolers, were met by a doubling of *tortilla* consumption, and much smaller (one-third) increases in legumes and meat. Consumption of dairy products decreases. By this age, children are eating a diet similar in pattern to that of adults. Available iron, ascorbic acid and retinol intakes are deficient on average in both groups. The phytate:iron and phytate:ascorbic acid ratios are similar to adult values.

Table 8.7: Dietary intakes of preschoolers and schoolers.

	PRESCHOOLERS (n=58)		SCHOOLERS (n=94)	
	Mean	SD	Mean	SD
Energy (kcal)	1085	282	1865	464
Protein (g)	32	8	55	13
Fiber (g)	13	5	25	8
Animal (kcal)	121	89	120	78
Plant (kcal)	964	277	1745	461
Tortilla (kcal)	588	260	1277	423
Legumes (kcal)	61	42	99	63
Pulque (kcal)	8	29	19	60
Meat (kcal)	30	21	46	33
Dairy (kcal)	53	70	35	55
Iron (mg)	12	4	21	6
Ascorbic (mg)	16	11	22	15
Heme Fe (mg)	0.22	0.23	0.30	0.35
Non-heme Fe (mg)	11	4	21	6
Avail. Fe (mg)	0.5	0.2	0.9	0.3
Phytate (mg)	1661	716	3413	1162
Phytate:Iron	34	9	39	7
Phyt.:Ascorbic	187	94	338	159

Non-anemic preschoolers consumed more dairy products ($p<0.07$); seventy percent of the preschoolers for whom their mothers reported no dairy foods during the study period were anemic. Sixty-three percent of the energy from dairy products came from fresh cow's milk and an additional 17% from powdered milk. Low serum ferritin is associated with consumption of more animal products, specifically dairy foods ($p<0.05$), and low plasma B_{12} with eating more *tortillas* ($p<0.10$).

Anemic schoolers have lower intakes of heme iron ($p<0.09$). Their risk of iron deficiency is associated with *pulque* consumption. This was verified by Fisher's exact test, two-tailed, $p<0.10$; because *pulque* was not consumed by all schoolers, the chi-square test was used to compare those schoolers who never drank the beverage with those who reported consumption. Approximately one-third of schoolers reported *pulque* consumption during the study, with average daily intakes in these children ranging from 3-473 kcal (inter-quartile range 16-52). B_{12}-sufficient schoolers ate more legumes ($p < 0.08$).

Changes by Season in Children

Season affected both food consumption and ferritin levels. For preschoolers, summer (pre-harvest) is a season of higher *tortilla* consumption ($p < 0.01$), reflected in higher intakes of energy, carbohydrate, fiber, non-heme iron ($p < 0.05$) and ascorbic acid ($p < 0.10$). Plasma ferritin levels of children whose blood was drawn in the summer were higher ($p < 0.04$). In contrast, schooler's food intake was higher in the post-harvest winter season when there are significantly greater intakes of protein, iron including heme, non-heme and available, higher phytate ratios, and meat and eggs. Hemoglobin and plasma B_{12} levels of children tested in the winter are higher ($p < 0.001$ and $p < 0.002$ respectively) while folate levels are higher in summer.

Relationships with Morbidity, Parasites and Anthropometry in Children

Neither growth rates nor attained size (Z-scores) of anemic vs. non-anemic preschoolers were significantly different. Children with sufficient iron stores (plasma ferritin) grew more quickly in weight (median 2.21 kg/year vs. 1.84 kg/year, $p < 0.02$) but not in height. In schoolers, there were no associations between anemia or plasma nutrient levels and either growth or attained size.

Reported morbidity (% of days ill) was (for anemic vs non-anemic) 62 vs 81 % in preschoolers and 13 vs 15% in schoolers; preschoolers are ill more frequently. Half the anemic and 41% of the non-anemic preschoolers showed evidence of abnormal parasite presence by the age of 31 months. Parasites infected 79% of anemic schoolers and 89% of non-anemics. Thus, there was no more reported illness or parasite infestation in anemic children than for peers who were not anemic. The same was true for deficient plasma levels of nutrients.

Summary of the Micronutrient Situation

Anemia was found in one third to a half of the men and women. The ferritin and plasma B_{12} measures show that iron and/or B_{12} stores are inadequate in a substantial portion of the sample. As expected, iron deficiency is rare in men and most evident in pregnant women. Two-thirds of the pregnant women studied had low plasma ferritin levels, but for many this was a physiologic event that self-corrected after delivery. Nonetheless, low plasma ferritin accompanied 67% of the low hemoglobin values in pregnant women, a clear indication of iron-deficiency anemia.

In adults, there was a higher risk of anemia for those individuals whose usual diet is more heavily dependent on plant products *(tortillas)* and who consume fewer animal products. Such diets contain substantially more fiber and phytate, so that although the total intake of minerals is not low, bioavailability is poor. Therefore it is not surprising that anemia is associated with dietary measures that take into consideration phytate and its inhibiting effect on mineral absorption. As no association was found between diet and iron deficiency (low ferritin), the high phytate ratios associated with anemia may be indicators of diets generally low in available micronutrients as well as low available iron. This is supported by indicators of better diet quality (energy from animal products, meat (g)) being associated with adequate plasma B_{12}, while those variables associated with an over-reliance on *tortillas* were associated with lower B_{12} levels. *Tortillas* also have added calcium from the lime treatment which probably further reduces absorption of non-heme iron.

Children had an even higher prevalence of anemia - about 69% at both ages. (Using hemoglobin rather than hematocrit, the prevalence increases to 80% for preschoolers). Iron depletion is also common, especially in preschoolers (42%) compared to schoolers (16%). Preschoolers have less anemia if they drink more milk, and by far the majority of those not given milk were anemic. Drinking more milk is associated with a reduction in plasma ferritin, probably because it supplies sufficient B_{12} for the iron to be used for hemoglobin synthesis. In Chapter Fourteen we see that milk is also associated positively with the growth of these children. More predictably, schoolers have more anemia if they eat less meat.

No individual had low plasma folic acid. Although serum or plasma folate does not reflect folate stores as reliably as red blood cell folate, it does reflect recent folate intake. As described in Chapter Six, folate intakes were generally adequate, due to frequent consumption of beans, corn *tortillas* and uncooked *salsa*. There was no seasonality in plasma folate.

There was a remarkably high prevalence of low plasma B_{12} levels, which occurred alone and/or in conjunction with iron deficiency in all groups studied. In the women low plasma B_{12} occurred most frequently during lactation. Plasma and milk B_{12} of anemic lactating women were significantly less than in non-anemic lactating women. Milk B_{12} concentrations in over half of the samples were below a level associated with adequate B_{12} status in infants. Moreover, in women who became anemic during lactation after hemoglobin-sufficient pregnancies, plasma ferritin levels returned to normal suggesting a deficiency of some other erythropoietic nutrient, such as vitamin B_{12}. Respite from menstrual loss of vitamin B_{12} does not compensate fully for its continuing demand during lactation, which lasted for approximately 18 mo on average. This contrasts with the situation for iron, where status is usually improved during lactation. Thus, long lactation may put women with marginal B_{12} status at risk of B_{12} deficiency as well as jeopardizing infant B_{12} status through inadequate amounts of the vitamin in breast milk.

Deficiency of this vitamin was also frequent in children, especially the preschoolers (41%) but also the schoolers (22%). Low storage of the vitamin during fetal development, followed by low amounts in maternal milk and a weaning diet that supplies only a small amount of animal products would exacerbate the risk of this vitamin deficiency for children. Although better dietary quality (specifically cow's milk in the diets of preschoolers) was associated with adequate plasma B_{12} levels, other factors may also explain the high prevalence of this deficiency. In a population in which parasites are endemic, it is difficult to dismiss the role of impaired absorption. Giardiasis, common in Solís, may cause a deficiency of this vitamin. Although there was no association between the presence of parasites in stools, and anemia or nutrient deficiency, our methods did not quantitatively measure parasite load.

Three to 13% of women's anemia could not be explained by iron and/or B_{12} deficiency. In men, where iron deficiency is less common, 30% of the anemia was associated with B_{12} deficiency and the other 70% could not be explained by iron, B_{12} or folate status. No explanation could be found for about half of the anemia in children. Other nutrient deficiencies that affect erythropoiesis may be involved, such as vitamin A.

Policy Implications

- The Solís sample is typical of rural populations where the diet consists primarily of cereals high in fiber and phytate, and contains few animal products, and where parasitic and bacterial infestations may impair nutrient absorption. In such populations anemia is highly prevalent in all age and sex groups. In Solís it was a major public health problem even in very young children and adult men, groups not usually considered to be at greatest risk.

- Anemia is generally assumed to be caused by iron deficiency alone, and is treated by administering iron supplements to individuals, or prevented in the population by iron fortification of foods. Iron deficiency was certainly very prevalent in preschoolers and women, especially during pregnancy. However, in this rural population, and probably in many others, multiple nutrient deficiencies are responsible. For example, in virtually none of the adult men was it caused by iron deficiency. This calls into question the appropriateness of supplementing with iron alone.

- Vitamin B_{12} deficiency is highly prevalent in all age and sex groups and is associated with anemia. Lactating women and preschoolers are at greatest risk. Because vitamin B_{12} deficiency causes impairment of neurologic function there is an urgent need to determine whether the degree of deficiency seen in pregnancy, lactation and early childhood in this population affects neurobehavioral development adversely.

- Existing WHO studies of anemia prevalence used older methods of B_{12} assessment which over-estimated plasma levels substantially. A re-evaluation of the situation is needed in other locations. In addition, given the probability of its multiple nutrient etiology, anemia surveillance programs should consider carefully the type of measures to be made, their interpretation, and the adequacy of intervention strategies.

- Further investigation is needed to establish the causes of the B_{12} deficiency. Possible reasons identified here include prolonged lactation (for the mother), vitamin B_{12} deficient breast milk, and a low intake of animal products. Subclinical parasitic infections may also be implicated but these were not evaluated in the CRSP.

- Folic acid deficiency is generally considered to be the second most likely cause of anemia, after iron deficiency. However, with the plant-based diet of the Solís Valley intakes of folate were more than adequate and no individual had evidence of inadequate folate consumption. This is probably true for many rural populations in poorer countries, but this remains to be verified.

- A substantial proportion of the anemia was not explained by either iron or B_{12} deficiency - 13-30% in women, about 50% in children and 70% in men. Other nutrient deficiencies, such as vitamin A, may be causing anemia in this population.

- The total intake of iron is not a useful predictor of anemia, which is not surprising given the suspected multiple deficiency etiology. However, the intake of some foods provides a better prediction. Preschoolers consuming more milk and meat (heme iron), and fewer *tortillas*, had less anemia and risk of vitamin B_{12} deficiency. Schoolers and adults with a dietary pattern based more on *tortillas*, and less on animal products, are more likely to be anemic. Thus, an increased availability of animal products is likely reduce anemia and vitamin B_{12} deficiency in this population. Currently, dietary quality is inadequate.

- Strategies for long-term dietary quality improvement, in addition to supplementation or fortification, should be considered as the best way to correct multiple micronutrient deficiencies because it is unclear which specific deficiency is limiting functions such as growth and other aspects of development.

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Chapter Nine.
Morbidity in Children and Adults

Introduction

The Importance of Morbidity

The importance of including morbidity in research aimed at understanding the consequences of malnutrition is widely acknowledged. The most well recognized morbidity and nutrition relationships are (i) the confounding effects of morbidity, especially diarrheal diseases, on growth, (ii) the synergistic effects of concurrent morbidity and infection for child mortality, and (iii) the role of morbidity in exacerbating the negative effects of low nutrient intakes.

With respect to psychological development in children, morbidity may be a major confounding variable influencing the relationship between malnutrition and psychological development. In the Kenya CRSP Neumann and colleagues have shown that "girls with more illness in the 18 to 30 month period performed less well [on psychological tests] than their female peers in all areas except motor development" [1]. Illness frequency also influenced maternal behaviors, such as "physical care" and "holding." Because the Kenyan children who experienced more illness played and vocalized less, it is likely that morbidity affects opportunities for stimulation and learning, including exploratory behavior in young children and school attendance in older children.

In adults, morbidity can influence household well-being and the ability of the household to acquire food, which may have serious, far-reaching consequences for household members, especially in conditions of rural poverty. Until recently, adult morbidity in developing countries has received relatively little attention. However, there is now increasing awareness of the role of adult morbidity in household functioning and its consequences for children.

Obtaining Accurate Morbidity Data

As described in Chapter Three, this study used the common and logistically efficient method of routine household monitoring to obtain morbidity data. However, there is some evidence to suggest that data obtained from respondents who are asked to report on the health status of household members is subject to various forms of inaccuracy [2]. Some of the differences between respondents' reports and physiological morbidity result from cultural differences between interviewer and interviewee in the interpretation of questions. For example, in Nigeria, asking mothers whether their child had " diarrhea" rather than asking about the number of loose stools the child had passed produced a significantly higher number of cases [3]. Another source of error is differential willingness to report illness, as exemplified by the tendency for women in developed countries to report more symptomatology than men. Thus, it is important to examine morbidity data for bias and to interpret results with caution. An additional problem is asymptomatic (subclinical) disease, including parasitic infection, which may affect nutrient absorption, utilization and requirement, but cannot be detected by questioning or routine physical examinations.

Morbidity in Adults

Frequency of Illness

Tables 9.1 and 9.2 show the frequency with which adults became sick -- or more correctly stated, with which they reported symptoms of illness. These tables show that at the weekly visit, women reported having symptoms more often than did men. For example, only 36% of the women but 62% of the men never reported being ill over the course of the household monitoring. The tables are not corrected for missed visits; that is, if a household was not visited on a given week, or the lead male was not present, the opportunity to report an illness does not occur. The frequency of missed visits is less than 10%, but the frequency of absence of adult males is much higher, and may account, **in part**, for the male/female differences. Differences in willingness to acknowledge and report symptoms, as well as differences in incidence, are also involved in the explanation of the differences by sex.

Proportional Morbidity by Illness Category

Table 9.3 presents the proportional morbidity of symptom categories for men and women. For adults, the symptoms frequently encountered in the "other" category included muscular-skeletal problems, and urinary tract complaints, and, for women, reproductive system symptoms. Respiratory symptoms also claimed a large portion of episodes, whereas as problems of the gastrointestinal tract were rarely reported, in spite of the high rates of parasitic infection and endemicity of GI pathogens. Diarrhea and intestinal pain may be so common in this population that they are regarded as a normal part of life, and not worth reporting except when the condition becomes very severe.

Seasonal Effects

There is some seasonal variation in the types of symptoms reported, but little over all change in the rate of total reporting of illness. Lower respiratory symptoms increase in the cold winter months (November-February), and the common cold showed increases in November and again in March. There is a striking increase in the "other" category during the harvest season, which was particularly marked for women. The harvest entails a great deal of hard physical labor on

Table 9.1: Number of visits with illness by symptom category: adult men.

	Number of Visits With Symptoms							
	None		1		2		3+	
Symptom Category	N	%	N	%	N	%	N	%
Any Illness	177	(62)	75	(26)	22	(8)	12	(4)
Fever	270	(94)	15	(5)	1	(1)	0	
Gastrointestinal	278	(97)	5	(2)	2	(1)	2	(1)
Upper Respiratory	261	(91)	22	(8)	2	(1)	1	(1)
Lower Respiratory	256	(90)	24	(8)	5	(2)	1	(1)
Common Cold	236	(83)	38	(13)	11	(4)	1	(1)
Other	230	(80)	46	(16)	7	(2)	3	(2)

N = 286; Median Length of Observation Period = 13 months

Table 9.2: Number of visits with illness by symptom category: adult women.

	Number of Visits With Symptoms							
	None		1		2		3+	
Symptom Category	N	%	N	%	N	%	N	%
Any Illness	103	(36)	62	(22)	50	(17)	73	(25)
Fever	241	(84)	40	(14)	5	(2)	2	(1)
Gastrointestinal	267	(93)	20	(7)	0		0	
Upper Respiratory	220	(76)	56	(20)	8	(3)	4	(2)
Lower Respiratory	206	(72)	57	(20)	16	(6)	9	(3)
Common Cold	176	(61)	59	(20)	35	(12)	18	(6)
Other	169	(59)	66	(23)	23	(10)	25	(7)

N = 288; Median Length of Observation Period = 14.5 months

Table 9.3: Proportional morbidity rate by illness categories.

ADULT MALES (N=286)

Symptom Category	# visits with symptoms	Morbidity rate
Fever	17	7.5
Gastrointestinal	13	5.8
Upper Resp.	28	12.4
Lower Resp.	36	16.0
Common Cold	62	24.8
Other	69	30.7

ADULT FEMALES (N=288)

	Non-pregnant		Pregnant	
Symptom Category	# visits with symptom	Morbidity rate	# visits with symptom	Morbidity rate
Fever	42	8.1	14	8.9
Gastrointestinal	13	2.5	9	5.7
Upper Resp.	67	12.9	18	11.4
Lower Resp.	78	15.0	28	17.7
Common Cold	143	27.4	46	29.1
Other	178	34.2	43	27.2

Proportional Morbidity Rate = No. of visits with symptom category/total visits with symptoms x 100

Table 9.4: Health history (% adult men and women).

	Adult Females (N = 252)	Adult Males (N = 195)
Surgery	15.5	20.5
Trauma	7.5	45.6
Allergies	3.2	3.1
Hypertension	2.0	4.1
Convulsions	1.2	1.0
Cardiopathology	0.4	0.5
Diabetes	0.0	0.5

the part of both men and women, a feature that is reflected in increased muscular-skeletal problems. For both men and women there were also modest increases in reported diarrhea or GI problems during the harvest period, but not during the rainy season.

Chronic Illness

The adult men and women in the study reported low rates of chronic disease at the time of their first clinic interview. However, rates of trauma and surgery are high, particularly for men. The results are shown in Table 9.4. In giving their medical history, 4.1% of men and 2% of women reported hypertension. However, for men, the rates of hypertension on physical examination were substantial higher. Close to 9% of the sample had systolic readings above 140 mm, and 18.4% had diastolic pressure above 90 mm. Among women the percent with systolic readings above 140 mm was 1.6 and diastolic above 90 was 2.8.

Morbidity in Children

Tables 9.5 to 9.7 describe the number of visit days with symptoms. The sample sizes are larger in these tables because they include non-target children in the study households that were in the same age range as the index children. These non-target children did not meet the selection criteria for target status. However, because all individuals in the household were included in the weekly morbidity monitoring, these non-index children are included in these analyses.

A large number of children were without reported illness on any visit day: 37% of infants, 29% of preschoolers, and 56% of school-aged children. For all three categories of children, upper respiratory illness was the most frequently reported with 48% of infants, 59% of preschoolers, and 34% of school-aged children with at least one episode. The next most common were the common cold and lower respiratory illness. Rates of gastrointestinal illness and fever were highest in preschoolers with 30% ever having fever and 35% ever having gastrointestinal symptoms. In contrast, gastrointestinal symptoms were quite low for school-aged children (4%) and about the same for preschoolers as infants (27%). Fever was less of a problem in infants (13%) and school-aged children (11%) than for preschoolers.

Rates of Reporting

For all types of subjects -- adults and children -- the rates at which symptoms were reported to investigators by the female household head are very low compared to many other populations in developing countries. For example, in their cross cultural review of diarrhea incidence, Snyder and Merson [4] found that the **median** number of episodes of diarrhea in children under 5 years of age in developing countries is 2.2 to 3 episodes per year. Similarly, throughout the world, episodes of respiratory infection tend to occur 6-8 times per year, whereas the median in our sample is 1.

Several factors may explain the low rates. The first is methodology. The incidence rates in most studies are based on interview procedures in which respondents are asked to report about symptoms over a period of time, usually one, two or four weeks. Our figures are based on repeated one day records. As described in Chapter Two, during most of the data collection period, interviewers inquired **only** about whether any family members had symptoms or illness on the day of the interview. Whenever an active case was identified, the interviewer then asked about when each symptom began. The end of the episode was determined through subsequent visits. Thus, the length of episodes was also obtained, but only for cases that were active on the day of the interview.

Realizing the weaknesses of the original morbidity protocol, the interview schedule was modified by adding, at the end of each visit, a recall of symptoms occurring between visits but not present on the day of the interview. This modification occurred seven months before the end of the field phase of the project, and makes possible an estimate of the number of symptom episodes that were missed by asking only about the day of the interview.

Table 9.8 shows the results of an analysis in which all illness episodes for all index subjects are combined. As the probability of missing an episode is greater than for those of short duration, the percent of missed episodes varies by the length of the episode. Sixty-two percent of episodes of just one day's duration were missed, whereas about one-fourth of the episodes of five or six days duration were not captured with the original data collection protocol.

The figures in Table 9.8 explain part of the difference between the Solís Valley data and the rates of illness commonly reported in morbidity surveys in developing countries. However, they still fall short of the rates that would be expected.

Table 9.5: Number of visits with illness by symptom category: infants.

	Number of Episodes (N=131)							
	None		1		2		3+	
Symptom Category	N	%	N	%	N	%	N	%
Any Illness	48	(37)	29	(22)	21	(16)	33	(25)
Fever	114	(87)	14	(11)	2	(2)	1	(1)
Gastrointestinal	96	(73)	18	(14)	15	(12)	2	(2)
Upper Respiratory	68	(52)	26	(20)	19	(15)	18	(13)
Lower Respiratory	91	(70)	28	(21)	6	(5)	6	(5)
Common Cold	83	(63)	28	(21)	12	(9)	8	(7)
Other	113	(86)	13	(10)	4	(3)	1	(1)

Table 9.6 Number of visits with illness by symptom category: preschoolers.

	Number of Episodes (N=131)							
	None		1		2		3+	
Symptom Category	N	%	N	%	N	%	N	%
Any Illness	45	(29)	27	(17)	22	(14)	63	(40)
Fever	110	(70)	35	(22)	8	(5)	4	(3)
Gastrointestinal	102	(65)	32	(20)	16	(10)	7	(5)
Upper Respiratory	65	(41)	33	(21)	24	(15)	35	(13)
Lower Respiratory	91	(58)	38	(24)	16	(10)	12	(8)
Common Cold	82	(52)	38	(24)	19	(12)	18	(12)
Other	127	(81)	21	(13)	5	(3)	4	(3)

Table 9.7: Number of visits with illness, by symptom category: school-age children.

	Number of Episodes (N=190)							
	None		1		2		3+	
Symptom Category	N	%	N	%	N	%	N	%
Any Illness	107	(56)	46	(24)	16	(8)	21	(12)
Fever	169	(89)	18	(10)	2	(1)	1	(1)
Gastrointestinal	184	(96)	5	(3)	1	(1)	-	
Upper Respiratory	125	(66)	39	(21)	11	(6)	15	(7)
Lower Respiratory	154	(80)	28	(15)	5	(3)	3	(2)
Common Cold	145	(76)	33	(17)	9	(5)	3	(2)
Other	152	(80)	27	(14)	8	(4)	3	(1)

Table 9.8: Number of episodes detected by each collection method.

	Length of Episode in Days						
Recall Protocol	1	2	3	4	5	6	7+
Original	11	16	18	36	36	40	214
Original + Addl. Question	29	37	40	54	46	54	228
Percent of Episodes Missed by Original	62	57	55	33	22	26	6

Total Missed Episodes = 24%

A second potential influence on illness reporting is the relationship of the respondents to the interviewers. In general the families were highly cooperative with all aspects of the CRSP project and graciously endured much more intrusive procedures than the brief morbidity monitoring interviews. The data were collected by young physicians who were well known to the families and who staffed the community health outposts. It is conceivable that the youthfulness of the physicians and the health aides led to a lack of confidence in them from some respondents and thus to a reluctance to discuss symptoms. There is, then, a possibility that situational factors in the administration of the data collection procedures contributed to the low rate of reporting ill health.

Finally, it seems likely that the morbidity monitoring data reflect the operation of a general cultural tendency to "down play" or "ignore" illness, particularly in adults.

Reporting Bias and the Social Correlates of Morbidity

The low rates of reported symptoms raise questions about how to use these data in multivariate analyses that are aimed at understanding nutrition-morbidity interactions and in controlling for the effects of morbidity in tests of relationships between nutrition and functional outcomes. The most important issue is whether there is reporting bias in the sample.

The difficulty in testing for bias is that there may be differential morbidity, for example, associated with differences in socioeconomic status, for which there are no independent measures in our data set. The relationships between social characteristics and morbidity can be described statistically. However, it is not possible in these data to distinguish between reporting bias and actual differences in the experience of illness, because the physician verification of symptoms was limited to individuals who reported complaints. Individuals who did not report symptoms were not examined. Nonetheless, it is useful to examine the data further to identify patterns of illness reporting that may provide insights into the relationships of social factors with morbidity, or, alternatively, the social differentials in reporting biases.

As all the morbidity variables (both chronic conditions and illness episodes) have a large proportion of subjects with zero frequency, these variables are best treated as categorical measures for the purposes of statistical analysis. The social variables were also recoded into nominal categories, and the examination of associations between social characteristics and morbidity was assessed through relative risk analysis and chi square tests. For these analyses, individuals are classified as having the symptom on the basis of at least one reported episode over the course of the study. Multiple episodes of the same symptom are not considered so that an individual contributes a "case" only once to each analysis.

The following social variables were used in the analyses: i) literacy, ii) socio-economic status, and iii) and the appearance measures of maternal management. Literacy was divided into two categories: "functionally literate" and "non-literate," based on self-reported reading and writing skills and reported reading activity. The SES scale was divided at the median, as were the appearance (maternal management) variables. The social variables were analyzed in relation to six symptom categories, and, from the clinical history, the reporting of surgery or trauma.

Relative Risk of Symptoms

Table 9.9 presents the results for analyses that identified significant differences in relative risk associated with the selected social variables. The symptom categories for which significant associations with social characteristics were identified are mainly confined to two symptom categories -- respiratory infection and fever (in adults). For children and adults, episodes of respiratory infection are reported more commonly by women who had higher maternal management scores. On the other hand, fever in adults was reported at a significantly higher frequency by women with lower maternal management scores. Not shown on the table were significant differences in an experience of previous surgery and trauma reported more commonly, at the initial health history interview, by men and women with higher SES ratings.

Discussion and Conclusions

From an anthropological perspective, morbidity reporting can be regarded as a form of behavior, in which biases in reporting provide insights into the nature of the "culture of health and illness" operating in a society. The cultural model that underlies reporting behavior is likely to vary cross-culturally, but there may also be commonalities that cross-cut cultural differences. For example, the general tendency for women to be more willing than men to acknowledge illness appears to characterize a wide variety of situations.

Some of the apparent bias in reporting behavior in Solís Valley may be explained by a model that focuses on the issue of illness recognition. In virtually all cultures once a household acknowledges that one of their members is ill, it becomes encumbent on someone to "do something" about the problem. The actions may be as simple as advising rest or preparing a soothing tea or as complex as initiating a search for care outside of the household. It may also be hypothesized that within most communities the households or families that are experiencing greater stress or that are coping less well will be more likely to ignore signs and symptoms of ill health until they become severe. Social and financial resources are often required to respond to illness. If one ignores or fails to recognize a condition of ill health, actions that put further stress on scarce resources can be, at least temporarily, avoided.

Finally, it is also likely that more illness will be found in households with greater stress. Households in which mothers are not managing as well may experience a greater amount of illness. In the research population in the Solís Valley, lower maternal management scores were associated with poor housing conditions and larger households, factors that may affect rates of illness.

The results from the relative risk analyses fit the general model postulated above. From the model one would predict that women who are managing better will report symptoms of mild-moderate severity more often than will women in more stressful situations. On the other hand, if actual rates of illness are higher in the latter households, higher rates of symptoms indicative of severity would be expected. In most cultures fever is regarded as a mark of severity,

Table 9.9. Relative risk of symptoms by subject type.

Illness	Subject	Variable	Value	Relative Risk	95% Conf. Limits
Fever	Men	House app.	Less clean	5.8	1.3 - 25.3
		Child app.	Less clean	4.1	0.93 - 18.5
	Women	House app.	Less clean	2.1	1.1 - 4.0
		Mother app.	Less clean	1.9	1.1 - 3.5
		Child app.	Less Clean	2.0	1.1 - 3.8
Respiratory	Men	Child app.	Cleaner	0.54	0.33 - 0.88
	Women	Literate	Yes	0.76	0.61 - 0.93
	Infant	Child app.	Cleaner	0.63	0.42 - 0.95
	Preschooler	Child app.	Cleaner	0.78	0.59 - 1.0
	Schooler	Mother App.	Cleaner	0.70	0.46 - 1.0
Total Illness	Infant	Child app.	Cleaner	0.76	0.58 - 1.0
	Schooler	Literate	Yes	0.68	0.50 - 0.93
Diarrhea	Schooler	Literate	Yes	0.18	0.04 - 0.97

Adult men, N=286; adult women, N=288; infants, N=131; preschoolers, N=157; schoolers, N=190.

especially in adults. The finding that fever is more commonly reported by women with lower management scores -- both for their husbands and themselves -- is, therefore, in line with the model.

The findings that respiratory infection in children and adults, more total illness in infants and more diarrhea and other illness in school-age children are positively related to maternal management and literacy also fits the expectations from the model. Certainly, these symptom categories can also be severe, but most of the episodes were mild or moderate, as indicated by the additional data in the morbidity records [5].

The lack of relationships between social variables and report of fever in children is more problematic. The rate of reported episodes of fever is very low for all households, suggesting again, a general cultural tendency to avoid recognition of illness. However, mothers' willingness to report (or notice) fever in their children is apparently not related to their management characteristics or resources.

With respect to the CRSP project in the Solís Valley, it may be concluded that there is a bias or distortion in relation to risk, such that the morbidity data do not contribute effectively to analyses aimed at understanding nutrition-infection interactions. The extent to which generalized under-reporting further distorts the results and confounds the interpretation of the analyses is impossible to determine with the data at hand.

The model of reporting bias we have used to explain the results from the Solís Valley needs to be tested with new data, which is validated with clinical observations. Also, before it could be generalized to any other population, it clearly needs to be tested in other social and cultural settings. To the extent that similar patterns of reporting bias operate in other cultural situations, the results of morbidity surveillance, and even cross-sectional morbidity surveys, may require more careful assessment of bias than is generally the case at present. Moreover, in studies aimed at identifying the effects of nutrient supplementation or other public health interventions, the consequences may be a failure to show an effect when one does, in fact, exist. In addition, undetected subclinical infections may be much more frequent than those reported, even in the most rigorous morbidity surveys.

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Chapter Ten.
Fertility, Birthspacing, Breastfeeding and Birth Control

Introduction

As described in Chapter Two, levels of fertility are high in the Solís Valley, resulting in rapid population growth and high migration from the valley. High fertility leads to large households. In a population that is poor, extra mouths can result in poorer quality diets for all (Chapter Seven), and the dedication of scarce household economic resources to the feeding and clothing of many children. For the mother, poor diet quality accompanied by a series of pregnancies (followed by lactation) may engender the poor nutritional status of the mother with concomitant effects on her infants. This chapter describes some of the factors affecting fertility in the Mexico CRSP households. In addition, we document the relationship of birth intervals to the breast-feeding of infants.

Data Collection

As described in Chapter Three, extensive information on household demographic characteristics was collected, including the birthdates of persons in the household. Respondents were questioned concerning birthdates, and were asked for birthdate documentation. When birth date documentation was missing, the supervisor returned to the household. When confirming documentation was not available, this was noted in the census record. For children 96 percent of birthdates were confirmed.

Following recruitment, a clinical history was obtained from all subjects in the study, which included information on family health problems, the subject's past clinical history, and current health status (Chapter Three). Data on women's contraceptive practices, birth date of the index infant, weaning practices and date of *sevrage* (complete weaning from the breast) of the index preschooler are taken from these records.

Diet data were collected on food intake of the infant as described in Chapter Three. These data provide information on the amount and types of supplements to breast feeding. Milk volume and frequency of breast feeding were not measured. Diet records were used to cross-check the preschooler's *sevrage* date as recorded in the clinical history.

Menarche, Sexual Activity, and Children

For these analyses we employed a sample of 237 women with clinical history data (Chapter Three). Women were questioned by physicians at several points during the research concerning a wide variety of health issues and practices. Table 10.1 provides descriptive statistics concerning their age and sexual history.

The mean age of this sample was 33.4 years, most women being between 28 and 39 years of age. These women are somewhat older than would be representative of the general population. This is due to project protocols that focused on preschool and school-aged children (Chapter Three). The mean age at menarche for these women was 13.7 years, and the first reported sexual activity occurred around age 18 with 75% of women becoming sexually active by age 20. Eighty-two percent of women (not shown) reported giving birth about one year after the onset of sexual activity. The mean age at first pregnancy was 19.5 years (75% becoming pregnant by age 21). The median number of pregnancies and births was 6.

Use of Birth Control

Women in the Solís Valley have multiple sources of contraceptive services. These are provided on a free-basis by extension workers of the Ministry of Health, and most of the usual contraceptives are readily available at local health posts. Women were asked at the clinical history as to whether they were now employing any birth control. Sixty-three percent of women reported no use of birth control (Table 10.2). Oral contraception and injections were the principal contraceptive methods women reported as used (both having been used by 11% of women). Eight percent of women reported using the rhythm method, and 6% reported the sterilization of either the woman or her spouse (the questionnaire did not distinguish between the two). Only 27% of women reported any use of modern methods of birth control.

Use of modern birth control methods differed across community. The community with the largest proportion of women reporting use of contraception (44%) has a birth control clinic.

Birth Spacing

Table 10.3 describes the distribution of the age of the mother at the last birth, the last birth interval, and the time period since the last birth. The median length of the last birth interval was 26.7 months, or slightly over two years between births. This translates into 18 months between pregnancies (approximately 25% had less than one year between pregnancies).

As shown in Figure 10.1, there is a relationship between the mother's age and the length of the birth interval ($r=0.28$, $p=0.0001$, $N=230$). The increase in birth interval with age suggests increasing use of contraception or other methods of birth control with age. However, no relationship exists between the length of the last birth interval and current reported use of birth

Table 10.1: Distribution of age at menarche, onset of sexual activity, and birth of first child.

	N	Mean	SD	Q1	Median	Q3
Age at End of Study	237	33.4	7.4	28.2	33.6	38.9
Age at Menarche	228	13.7	1.3	13	14	14.5
Age at First Sexual Activity	237	18.5	2.9	17	18	20
Age at First Pregnancy	237	19.5	2.9	18	19	21
Number of Pregnancies	237	6.7	3.4	4	6	9
Number of Births	237	6.0	3.2	3	6	8
Number of Live Children Now	237	5.5	2.9	3	5	8

Table 10.2: Reported use of birth control*.

	N	%
Oral Contraceptives	28	11.8
Injection	26	11.0
IUD	6	2.5
Condoms	4	1.7
Rhythm	20	8.4
Tubal Ligation/ Vasectomy	14	5.9
Other	1	0.4
Use of Any Birth Control	87	36.7
Use of Pill, Injection, IUD, Condoms, or Sterilization	66	27.8

* Women sometimes reported use of more than one method

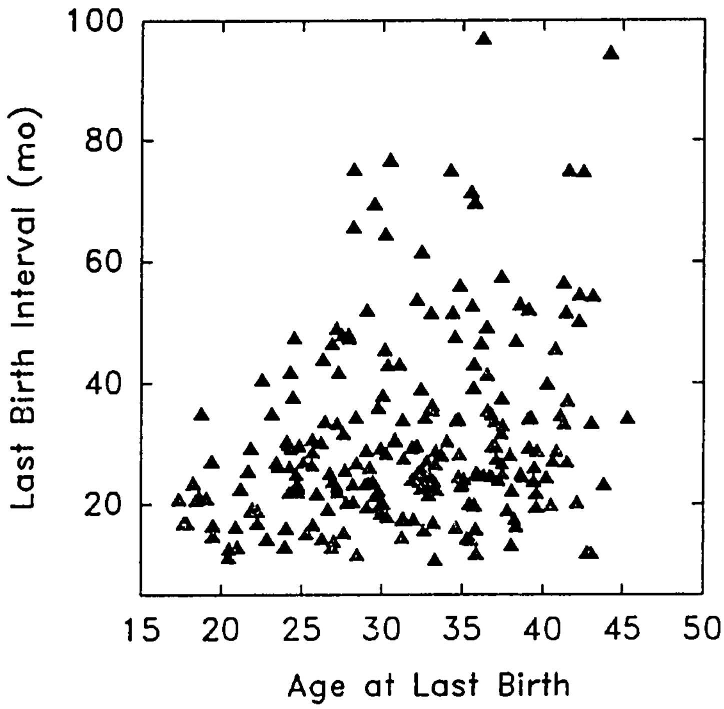

Figure 10.1: Relationship of mother's age to length of last birth spacing.

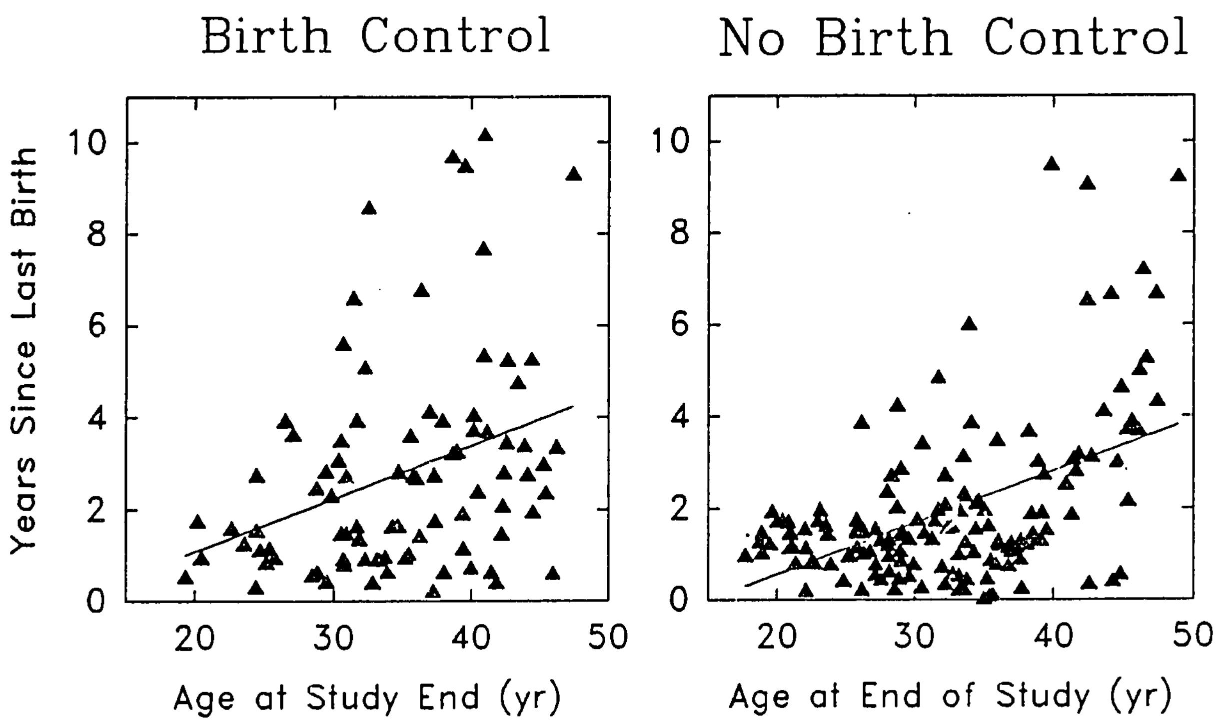

Figure 10.2: Relationship between mother's age and the time since last birth by reported use of birth control.

Table 10.3: Last birth interval, the last birth, and the number of births.

	N	Mean	SD	Q1	Median	Q3
Age at Last Birth	237	31.1	6.8	26.2	31.4	36.5
Time Since Last Birth (mo)	237	27.3	24.2	11.7	18.8	35.9
Last Birth Interval (mo)	237	31.1	15.4	21.3	26.7	35.7

control. An examination of the distribution of the time since the last birth showed a sizeable number of women (10%) with over five years since their last child. This suggested that current contraceptive use might be more applicable for the time since the last child.

Figure 10.2 shows the relationship between present age and the time since the birth of the last child by reported use of birth control. Multiple regression modeling using a dummy variable suggested that the strongest differences were between the non-use/rhythm and the modern birth control groups (Table 10.4). Separate regression models were fit to the two groups, and the differences in slopes and intercepts were tested for statistical differences [1]. The regression model indicates that use of birth control increased the length of time since the last child by an average of 10 months. Moreover, older mothers increased the length of time since the last pregnancy by 1.3 months for each year of their age.

Duration of Breastfeeding

Several studies have shown that lactation prolongs postpartum amenorrhoea, [2,3] although it is difficult to predict the duration of lactational infertility. Because many women in the Solís Valley breastfeed their children, some for long periods of time, breastfeeding may play in role in birthspacing in this population. Also, the spacing between the cessation of lactation and next conception may have health implications for the mother and new infant.

In the study population, nearly 100% of women breastfeed to some extent (see Chapter Ten). By the age of 8 months, 67% of infants were still receiving some breastmilk. Of the target preschoolers, 27% were still receiving some breastmilk 18 months after birth, and 10% were still breastfeeding at 24 months. Because of these long periods of lactation and the relatively short birth intervals in this population, breastfeeding sometimes continues into pregnancy. Of 65 mothers with target infants and preschoolers, 72% (47) were lactating at the conception of the target infant. Of these 47, 81% breastfed into the second trimester of pregnancy.

Statistical analyses on 40 mothers of target infants and preschoolers for which good weaning data are available shows extended lactation to be associated with shorter birth intervals (Table 10.5).

Table 10.4: Regression model for months since last child as predicted by age of mother and reported use of modern birth control (N=237).

Variable	Estimate	t	prob
Intercept	-20.53	-3.16	.0018
Age of Mother	1.36	7.11	.0001
Use of Modern Birth Control	8.91	2.84	.0050

R-square= .22
Root MSE= 21.54

Table 10.5: Mean birth intervals between target infant and previous child.

	N	Mean	SD	Q1	Median	Q3
Not Lactating at Conception	14	105.7	116.9	32.0	61.5	158.0
Lactating at Conception	26	458.2	129.4	394.0	443.0	521.0

This is consistent with prolonged breastfeeding reducing the fertility of some women via hormonal suppression of ovulation.

Conclusions

In the Solís Valley, most women have their first child at the age of 18-20 years, and many continue having children until menopause. The median time between birth and the next conception is approximately 18 months, and for 25% of women this period is less than 12 months. There is some use of birth control in these communities, and modern contraception appears to lengthen birth intervals in some cases. Even without use of modern birth control, birth intervals lengthen considerably with the age of the mother. This suggests that fertility may be regulated in part by changes in sexual behavior. It is likely that men and women regulate their sexual behavior in order to slow the coming of the next child. Also, prolonged breastfeeding appears to lengthen birth intervals in this population.

The apparently behavioral regulation of fertility in these households, combined with the much higher proportion employing modern birth control in the one community with a birth control clinic, suggests that an untapped 'market' for modern birth control may exist in these rural communities. However, use of birth control increased birth intervals by only 10 months. This suggests that birth control is used in this population primarily as a means of birth spacing rather than as a method of limiting the number of children. Therefore, a fertility-regulation campaign based on lengthening birth intervals via modern birth control and/or lengthened breastfeeding might be well received. Of course, increasing birth spacing alone will not completely solve the fertility problem that reduces household diet quality, increases the rural population, and leads to high rates of migration to urban parts of Mexico. However, any reduction in the number of mouths to feed would be beneficial.

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Chapter Eleven.
Pregnancy and Lactation: Importance of Mother's Size

Pregnancy and Lactation in Marginal Malnutrition

It is generally recognized that there are substantial differences between women in developing and industrialized countries concerning several aspects of pregnancy and lactation performance. For example, women from less well-nourished populations tend to have: lower maternal weight and height at conception, younger age at conception, lower pregnancy weight and fat gain, somewhat lower birth weight infants, higher prevalence of Low Birth Weight (<2,500 g), and a longer duration of lactation. However, there are many unanswered questions concerning these differences, including why pregnancy weight gain is so much lower and the extent to which this can be explained by low energy intake. Additional questions center around the effect of pregnancy and lactation on maternal nutritional status. (A description of the effect of pregnancy and lactation on iron and vitamin B_{12} status of Solís mothers was provided in Chapter Eight). In addition, little is known concerning how maternal nutritional status affects her *endowment* of nutrients to the fetus at birth, and the extent to which neonatal nutrient stores protect against inadequate infant intake from breast milk or other sources, or against infections in early life.

Pregnant women are usually advised on the importance of maternal diet during pregnancy, with the underlying assumption that increasing energy intake will improve the nutrient supply to the fetus, resulting in higher infant birth weight. The adequacy of maternal energy intake is generally assumed to be reflected in maternal pregnancy weight gain, an easily accessible measure of progress. The low pregnancy weight gain of women in developing countries is assumed to be caused by a lower energy intake. However, it has not been adequately recognized that *maternal body composition prior to conception* has a dramatic influence on subsequent events, including pregnancy weight gain. For example, even in the United States it is now accepted that fatter women at conception will gain substantially less weight during pregnancy than those who are thinner. This fact has led to recent revisions of the recommended weight gains for pregnant women, which are now based on body mass index (BMI) at conception or in early pregnancy [1]. Whether the inverse relationship between maternal fatness and weight gain is related to energy intake is unclear, nor is it known whether it occurs in less well-nourished populations in developing countries.

In this population we observed the very early growth failure of infants and the fact that higher birth weight infants are relatively protected from this growth faltering (Chapter Five). The general objective of the analyses presented in this chapter is to evaluate how maternal size and body composition prior to pregnancy affect subsequent events, including pregnancy weight gain and postpartum weight retention, energy intake during pregnancy and lactation, and infant size.

Fatter or heavier women may: use energy stores to provide the infant with more energy during fetal development; consume a diet higher in quantity and/or quality providing the newborn with higher nutrient stores; and/or produce milk that is higher in fat and energy (as observed in malnourished women in Bangladesh [2]) or micronutrients.

While not all of these possibilities can be answered here, the Mexico Nutrition CRSP has valuable data with which some of these questions can be addressed. In particular, investigation of the relative contribution of maternal body reserves and gestational nutrient intake has been impossible in most studies because relatively few women present for medical care prior to or early in pregnancy. Consequently data on maternal weight or body composition during the first or early second trimester are usually reported as the baseline from which subsequent change is determined. In Solís we have longitudinal data on a subset of women who were enrolled as mothers of target children and who subsequently became pregnant. Thus we can study anthropometry and food intake of these same women prior to conception and then during pregnancy and lactation. In addition we have the larger sample of women who were recruited at later stages of pregnancy, called here the "cross-sectional" sample.

These analyses were performed by Dr. Mary S. Lung'aho and are described in more detail elsewhere [3].

Collection and Analysis of Data from Pregnant Women and Their Infants

The subjects providing data for these analyses were all female heads of households who had at least one target child meeting CRSP age criteria, and were less than 5 months pregnant.

Anthropometric data were collected in the Solís clinic every 3 months from non-pregnant, non-lactating (NPNL) women. Once a NPNL woman was discovered to be pregnant, or a pregnant woman was enrolled, her anthropometry was measured every month through pregnancy and lactation. From the anthropometric data, additional indicators of maternal size and body composition, and gestational changes in these factors, were created. They included: Body Mass Index, BMI = weight (kg)/height (cm)^2; Body Fat Mass (BFM) and Lean Body Mass (LBM), from the formulae of Durnin and Womersley [4] based on 4 skinfolds, and Siri [5]; total gestational weight gain = the change in maternal body weight between conception and the time immediately preceding the birth of the infant; net weight gain = total weight gain minus the infant's birth weight; and retained weight, the difference between maternal weight at conception and postpartum (within two weeks of birth).

From individual food intake data, consumption of the following was calculated: nutrients, including energy (kcal), protein (g), fat (g), and carbohydrates (g); and calories and protein from animal and plant sources, as well as from specific foods that are of particular importance, i.e.

intakes from *tortillas*, *pulque*, meat and dairy products. A mean of 5 (range 2 to 8) days of food intake data were available for each woman per analysis period (defined below).

Other data used in these analyses include maternal age, parity, and socioeconomic status. Reproductive history data were collected as part of the clinical history obtained by physician interview upon a woman's entry into the study. In the absence of reliable data establishing an approximate date of conception the assumption was made that the period of gestation for every birth was 280 days. Dubowitz exams were used to assess gestational age in 32 of these infants, and none of them was premature. Assuming there were fewer post-date than early births, there will be a tendency to underestimate the size of changes during pregnancy.

To assess change over time in measures such as dietary intake, weight gain and skinfold change, time intervals were created. Trimesters are as follows: Tri1, conception to 93 days of pregnancy; Tri2, 94 - 187 days; Tri3, 188 - birth, by definition day 280 of pregnancy. Other intervals were created around conception, the ends of the first and second trimesters, and the time of birth. These periods of interest were extended by three-week (21-day) intervals to maximize the possibility of finding cases to fit the interval definitions. In lactation, Lactri0 includes 0 - 14 days postpartum, Lactri1 days 69 - 111 (approx. 3 months), and Lactri2 days 159 - 201 (approx. 6 months).

The Longitudinal and Cross-Sectional Samples

Data were subsetted for purposes of analyses into two major groups. The *longitudinal* sample contains those women on whom we were able to calculate *changes* throughout the whole of pregnancy. All these women had at least 1 measure of diet and anthropometry at conception, during each of the 3 trimesters of pregnancy, and during the first trimester of lactation. There are weights on 36 women and diet measures on 49. For 31 of the women, data were also available on infant birth weight, and on changes in maternal body weight and composition over the first 6 months postpartum.

Data from women lacking anthropometric and dietary data at conception and during the first trimester, but having data from the second and third trimesters, were added to form the larger *cross-sectional* group, which numbered in total 82 (and included the longitudinal group). One purpose of comparing this cross-sectional sample with the longitudinal subset was to confirm that associations seen in the relatively small longitudinal sample would be replicated in the larger one. Also, the cross-sectional sample was used for some postpartum analyses where early conception data were not needed.

Maternal Body Mass Index Groups

To further illustrate the pattern of relationships between maternal fatness at conception and changes in diet and anthropometry during pregnancy and lactation, the 36 women comprising the longitudinal sample were divided into terciles representing "low", "moderate" and "high" prepregnancy BMI.

Statistical Analyses

Pearson's product-moment correlations were used except for analyses involving diet and weight gain, where Spearman's rank-order correlations were used because of the skewed distributions. Bivariate analyses also included ANOVAs, and Tukey and Scheffe post hoc means comparisons tests to determine the existence of changes in maternal diet and anthropometry during gestation. Repeated measures ANOVAs were used to examine differences between groups of women in their patterns of weight gain, fat deposition and dietary intakes during gestation.

Description of Mother's Anthropometry and Diet

Anthropometry

At conception the women were between 18.0 and 44.6 years of age, with a mean age of 31 years for both the cross-sectional and the longitudinal samples. Only 5 of the 34 women with parity data had given birth to fewer than 5 children; 1 was in her first pregnancy, 4 were parity 2-4, 17 were parity 5-8 and 12 were parity 9-12. The variation in socioeconomic status was substantial.

Mean height was 152.8 cm, and mean weight at conception 55.3 kg (Table 11.1). The BMI ranged from 18.4 to 29.1. Initial skinfold thicknesses and limb circumferences were high, particularly those skinfolds measured on the body trunk. For example, in the United States Frisancho reported a mean of 16.2 mm for subscapular skinfold reference values for women age 30.0 to 34.9 years [6], compared to 22.7 mm in Solís. The mean triceps skinfold at conception was closer to that of US women [6], as was average initial body fat (31%). Body fat was higher than values for women in any of five developed or developing countries reported in a recent cross-country study [7]. The Mexican women carry more fat on the trunk, and less on the extremities, than the North American women from whom reference values have been derived. At conception none of the average anthropometric measures was different between the longitudinal and the cross-sectional samples.

Complete longitudinal data on weight change throughout pregnancy and lactation were available for 31 women. Body weight increased steadily throughout pregnancy and total mean gestational weight gain was 6.1 kg by the mid third-trimester (Table 11.2). Subcutaneous fat increased as early as the first trimester at the subscapular and suprailiac sites (Table 11.3). Fat deposition

Table 11.1: Maternal anthropometry, prepregnancy (N=36).

	Mean	SD	Minimum	Maximum
Weight (kg)	55.3	7.4	41.6	70.3
Height (cm)	152.8	4.9	140.6	161.8
BMI	23.5	2.6	18.4	29.1
Triceps (mm)	16.5	5.1	7.5	29.0
Subscapular (mm)	22.7	8.7	9.0	40.5
Suprailiac (mm)	21.8	8.9	6.8	40.0
Upper Arm Circ. (cm)	27.4	2.2	22.8	32.8
% Body Fat	31.3	5.1	16.9	40.1

Table 11.2: Changes in maternal weight during pregnancy and lactation (N=36).

	Mean	SD	Minimum	Maximum
Pregnancy				
Conception	56.2	7.0	44.1	70.3
Tri 1	56.7	6.9	43.1	72.7
Tri 2	59.3	6.4	45.6	73.2
Tri 3	62.3	6.5	47.4	74.8
Lactation				
Lactri 0	59.2	6.8	47.4	72.5
Lactri 1	59.0	6.9	47.8	72.8
Lactri 2	58.0	7.3	46.0	73.0

at these trunk sites increased throughout pregnancy while skinfolds on the extremities increased by early-mid pregnancy then declined slightly in the third trimester.

Skinfold thickness measures *increased* on average during the first trimester of lactation, and then declined gradually to 6 month post-partum values; the exception was the triceps skinfold which did not change much during pregnancy or lactation.

Table 11.3: Skinfold thicknesses during pregnancy and lactation (N=31).

	Triceps (mm)		Biceps (mm)		Subscapular (mm)		Supra (mm)		Sum of 4 (mm)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pregnancy										
Conception	16.7	4.9	27.7	3.5	3.7	8.7[b]	22.8	8.6[b]	71.0	22.8
Tri 1	16.4	4.0	27.4	3.3	4.4	8.5[ab]	23.7	9.2[ab]	71.8	21.6
Tri 2	17.0	5.3	28.2	3.5	5.8	7.5[ab]	25.4	7.6[ab]	76.4	20.8
Tri 3	16.1	3.5	27.1	2.8	6.1	6.6[ab]	25.9	7.4[ab]	75.2	17.9
Lactation										
Lactri 0	15.7	3.7	27.6	2.7	7.6	7.4[a]	30.6	7.8[ab]	85.5	19.0
Lactri 1	16.8	3.6	27.8	2.4	7.7	8.2[a]	31.5	7.6[a]	87.7	19.0
Lactri2	16.5	4.2	27.7	3.2	7.6	10.5[ab]	27.1	11.5[ab]	79.0	26.7

Means with the same superscript do not differ significantly.

Table 11.4: Energy and macronutrient consumption, prepregnancy (N=49).

	Mean	SD	Minimum	Maximum
Energy				
Total (kcal/day)	2118	661	782	3586
Animal (kcal/day)	119	139	0	601
Plant (kcal/day)	1999	623	782	3393
Animal (% total)	5.3	6.4	0	33.3
Plant (% total)	94.7	6.4	66.7	100.0
Protein				
Total (g/d)	58.4	19.2	21.2	109.7
Animal (g/d)	9.2	9.5	0	40.8
Plant (g/d)	49.2	15.5	21.2	91.6
Animal (% total)	14.1	14.0	0	58.1
Plant (% total)	85.9	14.0	41.9	100.0
Fat				
Total (g/d)	26.8	15.7	5.2	79.8
Pulque (% kcal)	8.1	7.0	0	26.0
Tortillas (% kcal)	70.5	13.4	37.4	97.4

Dietary Intake

There were from 2 to 8 (mean of 5) diet measures per individual in each interval of pregnancy and lactation. Mean energy intake prior to conception was 2118 kcal/d or 40.5 kcal/kg body weight (Table 11.4). About 5 percent was from animal products on average although some women ate none and others obtained as much as one third of their energy from this source. At conception mean daily energy intake from *tortillas* was 70% but ranged from 37 to 97%. Mean individual energy intakes from *pulque* ranged from zero to 26 percent. The mean protein intake was 58 g/d. At conception, fourteen percent of protein was from animal sources, with a range from 0 to 58%. There was great variation in fat intake, from 5 to 80 g/d, and on average it provided approximately 11% (range 5 - 27%) of daily energy.

Women consumed 246 kcal/day more during the last trimester of pregnancy compared to conception (although this increase was not statistically significant). However, intake per kg body weight was not increased at any time in pregnancy (Table 11.5). In contrast, intake did increase at the start of lactation (Table 11.5) even when calculated on a body weight basis. Intake of protein, fat, and energy from plant sources, followed a similar pattern. Neither the proportion of total energy intake accounted for by protein, or by protein from animal sources, changed during either pregnancy or lactation indicating that the quality of the women's diets did not change during this time.

Infant Characteristics at Birth

Infant birth weight averaged 3.26 ± 0.35 kg (range: 2.43 to 4.00 kg), or -0.13 Z (Table 11.6). Mean length at birth was 49.74 ± 2.00 cm or about -0.34 Z, and mean head circumference was 36.3 ± 1.3 cm. Ponderal index averaged 2.65 ± 0.22 with a fairly wide range of values. Birth weight and length were similar in the longitudinal and cross-sectional samples. Boys and girls had the same average weight, length, ponderal index, and head circumference, and their mothers had the same pregnancy weight gain and dietary intakes.

As for the CRSP infants as a group (Chapter Five), growth failure, identified as weight-for-age and length-for-age values failing to achieve NCHS reference values, was apparent by 3 months when weight Z was -0.31 and length Z was -0.95. By 6 months growth stunting was worse (weight Z = -0.95 and length Z = -1.31).

Maternal Weight Postpartum

The difference between maternal prepregnant and postpartum weights (retained weight) averaged 3.2 kg (Table 11.7), an increase of approximately 6 percent over weight at conception. Not surprisingly, most of the retained weight appears to be fat. Fat store changes during pregnancy averaged 2.4 kg, and ranged from a loss of 4 kg to a gain of 6.5 kg. Expressed as a proportion

Table 11.5: Maternal energy and macronutrient consumption, pregnancy and lactation.

	kcal/d (N=45)		kcal/kg (N=28)		Protein (g) (N=45)		Fat (g) (N=45)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pregnancy								
Conception	2110	681^{a*}	37.3	12.9	58.0	19.7^{a}	27.1	16.0^{a}
Tri 1	2192	633^{ab}	38.2	12.1	60.5	18.9^{ab}	31.0	18.2^{ab}
Tri 2	2235	537^{abc}	37.4	10.3	61.1	15.9^{ab}	32.0	18.0^{ab}
Tri 3	2356	678^{abcd}	36.9	12.4	69.0	22.4^{ab}	32.2	18.0^{ab}
Lactation								
Lactri 0	2654	734^{bcd}	43.1	13.9	73.5	22.4^{ab}	41.1	20.3^{ab}
Lactri 1	2718	707^{cd}	46.5	13.4	74.1	21.5^{b}	42.3	20.1^{b}
Lactri 2	2774	841^{d}	48.1	14.7	75.6	22.9^{b}	42.4	21.0^{b}

* Means with the same superscript do not differ significantly

of initial body weight, the change in fat stores ranged from a loss of approximately 6 percent to a gain of 14 percent, with an average increase of 4.7%. For comparison, average values for well-nourished women are 1.3 - 5.4 kg retained fat [1].

Relationship of Maternal Body Size Prepregnancy to Dietary Intake, Pregnancy Weight Gain and Maternal Weight Retention Postpartum

Maternal size before pregnancy had a strong influence on events during pregnancy and lactation. Heavier women at conception ate less energy and protein than thinner women, both prepregnancy as well as during gestation (Table 11.8). This was especially evident for energy intake per kg body weight (Table 11.9). While these relationships were stronger for measures of fatness from the extremities than from trunk sites, the patterns were consistent throughout. In addition, fat-free mass was an equally strong negative indicator of energy intake per kg.

Heavier women also had better quality diets, consuming a greater percent of their energy and protein from animal products (Table 11.10). Thinner women consumed more from plant sources. For example, weight at conception was positively correlated with average % kcal from animal sources during pregnancy ($r=0.31$, $p<0.05$) and negatively related to average kcal/day from

Table 11.6: Infant characteristics at birth.

	Mean	SD	Minimum	Maximum
Weight (kg) (N=28)	3.26	0.35	2.43	4.00
Length (cm) (N=25)	49.74	2.00	44.0	52.00
Ponderal Index (N=25)	2.65	0.22	2.24	4.09
Head Circ (cm) (N=25)	36.30	1.30	33.8	38.60

Table 11.7: Total gestational and maternal weight retained postpartum (N=36).

	Mean	SD	Minimum	Maximum
Total Weight Gain (kg)[1]	6.1	3.3	-2.5	13.0
Total Wt Gain (% initial)[2]	11.2	6.2	-3.9	23.3
Retained Wt (kg)[3]	3.2	3.4	-8.9	8.2
Retained Wt (% initial)	6.2	6.3	-14.2	17.3
Retained Fat (kg)[3]	2.4	2.4	-4.0	6.5
Retained Fat (% initial wt)	4.7	4.7	-6.4	14.0

[1] Gain calculated as difference between mean weight Tri 3 and weight at conception.
[2] Initial weight = weight at conception.
[3] Mean measurement in Lactri 1 minus mean measurement at conception.

plant sources ($r=-0.51$, $p<0.01$). For triceps skinfolds at conception, these associations were 0.35 ($p<0.05$) and -0.65 ($p<0.001$) respectively.

Those women who were fatter when they became pregnant also gained less weight during pregnancy. This relationship was not seen in the first trimester, but the triceps skinfold prepregnancy was negatively correlated with second trimester weight gain, as with mid-upper arm circumference ($p<0.10$). Total weight gain, especially when expressed as a % of initial weight, was most strongly negatively related to mother's fatness prior to conception (Table 11.11). Thus, women who were both heavier and fatter at conception tended not only to eat less, but also to gain less weight during pregnancy. The correlation between energy intake and weight gain was 0.41 ($p<0.05$) in trimester 2, 0.30 ($p<0.10$) in trimester 3, and 0.32 ($p<0.10$) overall. [Fatter women actually **lost** subscapular fat during pregnancy and regained it in lactation; see following section]. They also retained less of the weight gained in pregnancy (total

Table 11.8: Correlations between energy intake during pregnancy (kcal/day) and maternal anthropometry at conception (N = 36).

	Conc.	Tri 1	Tri 2	Tri 3	Total
Weight (kg)	-.26	-.23	-.41	-.34*	-.40*
Height (cm)	-.01	-.09	-.06	-.07	-.09
BMI	-.33*	-.27	-.42	-.37*	-.45**
Triceps (mm)	-.48***	-.47**	-.57**	-.48**	-.55***
Subscapular (mm)	-.27	-.30+	-.24	-.31+	-.33+
Suprailiac (mm)	-.16	-.19	-.28+	-.41*	-.33+
Upper Arm Circ. (cm)	-.40*	-.28	-.36*	-.25	-.35*
% Body Fat	-.32+	-.31+	-.36*	-.40**	-.43**
Body fat (kg)	-.30+	-.28+	-.40*	-.37*	-.42*
Fat-free Mass (kg)	-.16	-.12	-.38*	-.22	-.29+

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 11.9: Correlations between energy intake per kilogram during pregnancy (kcal/kg) and maternal anthropometry at conception (N = 36).

	Conc.	Tri 1	Tri 2	Tri 3	Total
Weight (kg)	-.53**	-.57***	-.71***	-.65***	-.69***
Height (cm)	-.21	-.30*	-.25	-.36*	-.34*
BMI	-.56***	-.57***	-.70***	-.64***	-.69***
Triceps (mm)	-.60***	-.67***	-.63***	-.70***	-.55***
Subscapular (mm)	-.50**	-.55**	-.50**	-.53**	-.54***
Suprailiac (mm)	-.36*	-.43*	-.51**	-.63***	-.64***
Upper Arm Circ. (cm)	-.63***	-.56***	-.62***	-.48**	-.61***
% Body Fat	-.52**	-.57**	-.62***	-.62**	-.64***
Body Fat (kg)	-.55***	-.59***	-.68***	-.65**	-.68***
Fat-free Mass (kg)	-.43*	-.46*	-.65***	-.56***	-.60***

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 11.10: Correlations between animal product intake during pregnancy (% kcal) and maternal anthropometry at conception (N = 36).

	Conc.	Tri 1	Tri 2	Tri 3	Total
Weight (kg)	.23	.21	.34*	.18	.31+
Height (cm)	.21	.30*	.25	.36*	.34*
BMI	.28	.09	.20	.21	.29
Triceps (mm)	.24	.31+	.34+	.11	.35*
Subscapular (mm)	.12	.19	.39*	.04	.27
Suprailiac (mm)	.20	.23	.35*	.12	.29+
Upper Arm Circ. (cm)	.14	.23	.39*	.26	.36+
% Body Fat	.17	.18	.33*	.03	.26
Body Fat (kg)	.21	.19	.38*	.12	.13
Fat-free Mass (kg)	.24	.18	.27	.24	.28

+ $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 11.11: Correlations between gestational weight gain and maternal anthropometry at conception (N = 36).

	Total	Total as % Initial	Retained Weight	Retained % Initial	Retained Fat
Weight (kg)	-.31+	-.46**	-.35*	-.47**	-.38*
Height (cm)	.01	-.10	.11	.01	.06
BMI	-.48**	-.48**	-.40*	-.52**	-.49**
Triceps (mm)	-.55***	-.64***	-.62***	-.68***	-.55***
Subscapular (mm)	-.33+	-.46**	-.40*	-.49**	-.49**
Suprailiac (mm)	-.37*	-.51**	-.35*	-.43*	-.47*
Upper Arm Circ. (cm)	-.46**	-.58***	-.46**	-.55***	-.40*
% Body Fat	-.31+	.45*	-.39*	-.50**	-.48**
Body Fat (kg)	-.33+	-.48**	-.41*	-.52**	-.47**
Fat-free Mass (kg)	-.23	-.27	-.19	-.31	-.19

+ $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

or as a percent of body weight) after their infant was born. Conversely, women thinner at conception tended to retain more weight postpartum.

Outcomes by Maternal BMI Tercile

In order to further illustrate the relationship between maternal body size at conception and later events, the women were divided into terciles (12 women per group) based on BMI at conception. Body Mass Index (BMI) is usually compared to the 1959 Metropolitan Life Insurance Company's reference values: underweight, BMI < 19.8; normal weight, BMI 19.8 to 26.0; overweight, BMI > 26.0 to 29.0; and obese, BMI > 29.0 [1]. Underweight generally corresponds to $< 90\%$, overweight to $> 120\%$, and obese to $> 135\%$ of ideal weight. Only two of the 36 women (BMI 18.4 and BMI 19.4) could be described as having a low BMI (< 19.8). None of the 36 Mexican women was obese (BMI > 29.0). BMI measures of 7 women exceeded the value proposed as the cutoff for "overweight". The mean BMI of the entire group was 23.7, with the mean values of the 3 terciles being 20.8 (range: 18.5 to 21.9), 23.5 (range: 21.9 to 24.0) and 26.5 (range: 24.0 to 29.0).

Data from the 3 groups were examined to determine whether differences existed at conception for demographic and anthropometric characteristics. No significant differences were found in maternal age, parity, socioeconomic status or maternal height. Comparisons among the 3 groups for gestational weight gain and maternal weight retention postpartum are presented in Table 11.12.

Patterns of anthropometric and dietary change were compared among the 3 groups of women. Mean weight changes from conception through lactation are presented for each of the groups in Figure 11.1. While there were significantly greater gains in the second and third trimesters than in the first among the two groups of women lighter at conception (low and mod BMI), this was not so among the heavier women (high BMI). The pattern of skinfold changes also varied by BMI group (Figures 11.2 to 11.4). In general, women of lower BMI showed greater increases in skinfold measures early in pregnancy, particularly at trunk sites. Higher BMI women failed to show these pronounced increases, and in fact appear to mobilize fat from the extremities throughout pregnancy, in particular from the triceps sites. In general, the changes on the trunk sites were of greater magnitude than those on the extremities.

Energy intakes for the 3 groups are presented in Figure 11.5. Mean intake at conception was 2642 ± 473 kcal in the low BMI group, 1847 ± 677 in the average group, and 2053 ± 513 in the high BMI group. Repeated measures ANOVA showed these means to be not significantly different. Expressed as kcal/kg body weight, however, the thinnest group consumed significantly more energy at conception and through the first two trimesters of pregnancy, compared to either of the other two groups until the moderate BMI group's intake increased. In early lactation the fattest group persisted in eating less than the other two, but dramatically increased their intake during lactation - eating nearly 800 kcal/day more at 6 months than in

Table 11.12: Three BMI groups: infant size through six months (N=7-9 per cell).

	Birth	Month 3	Month 6
Weight (kg)			
Low	3.08	5.22	6.53
Mod	3.31	5.65	6.94
High	3.36	5.61	6.93
Length (cm)			
Low	49.4	56.2	62.1
Mod	50.7	58.8	64.3
High	49.3	58.7	64.4
Head Circumference (cm)			
Low	35.7	39.5	42.4
Mod	36.7	40.3	43.4
High	36.4	39.8	42.9

Table 11.13: Mother's postpartum weight and infant size at three and six months: cross-sectional sample (N=64-70).

	Infant Weight			Infant Length		
	Month 1	Month 3	Month 6	Month 1	Month 3	Month 6
Weight	.36**	.32**	.34**	.29**	.32**	.37**
Height	.05	.17	.34**	.15	.35**	.40**
BMI	.42***	.29*	.20	.31*	.22+	.22+
Triceps Skinfold	.16	.11	.01	.06	-.03	.04
Biceps Skinfold	.09	.08	-.06	-.03	.02	.05
Subscapular Skinfold	.23+	.16	.09	.12	.14	.19
Suprailiac Skinfold	.14	.16	.11	.04	.09	.16
Upper Arm Circ.	.31**	.22	.24	.22+	.19	.22+
Arm Fat Area	.21	.16	.06	.10	.02	.08
Body Fat mass	.33**	.23+	.18	.23+	.21	.26*
% Body Fat	.22+	.11	.04	.09	.05	.11
Fat-free Mass	.36**	.33**	.37**	.39**	.41***	.42***

+p<0.10, *p<0.05, **p<0.01, ***p<0.001

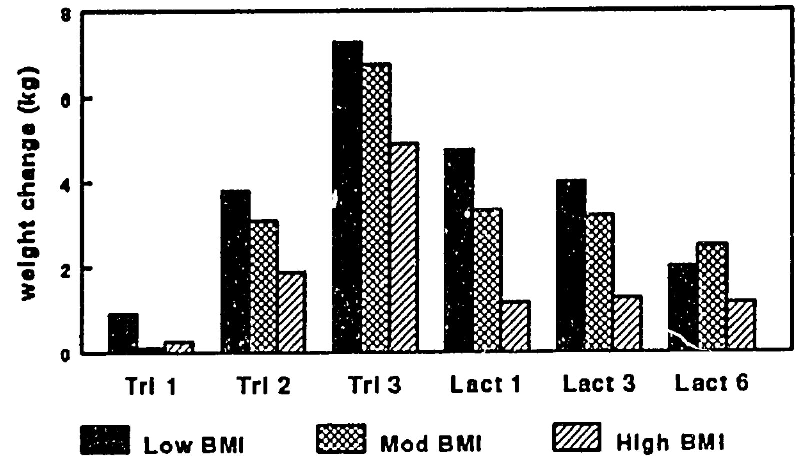

Figure 11.1: Body mass index (BMI) and weight change from conception through lactation.

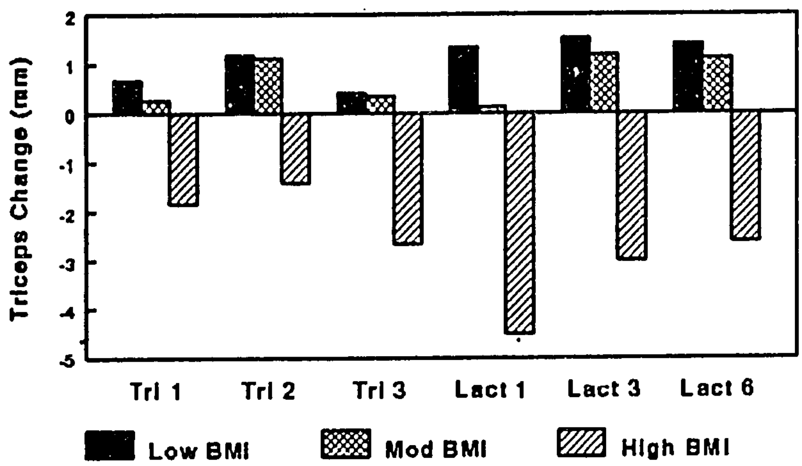

Figure 11.2: Body mass index (BMI) and change in triceps skinfold from conception through lactation.

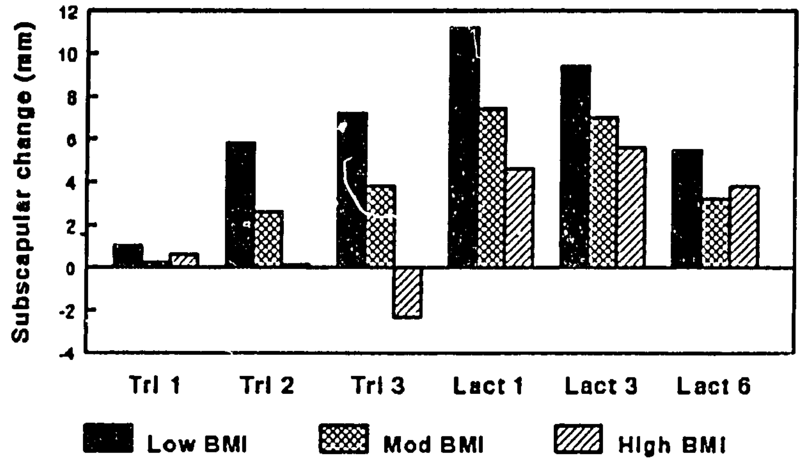

Figure 11.3: Body mass index (BMI) and change in subscapular skinfolds from conception through lactation.

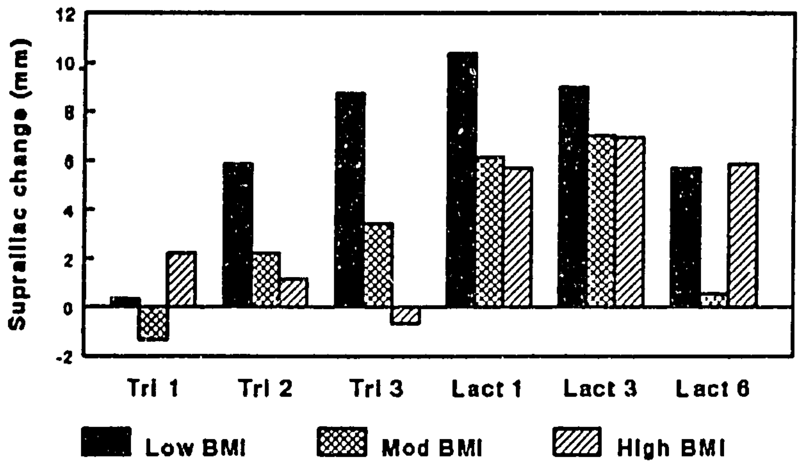

Figure 11.4: Body mass index (BMI) and change in suprailiac skinfolds from conception through lactation.

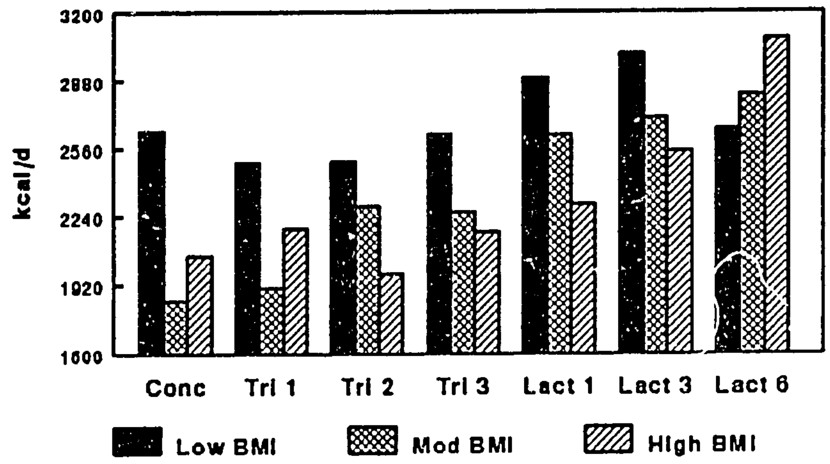

Figure 11.5: Body mass index and change in energy intake from conception through lactation.

months one to three. This helped the fatter women to regain the fat they had lost during pregnancy. At 6 months the women in all three groups were eating the same amount of food.

Effects of Maternal Body Size Prepregnancy on Infant Size

At birth, in general neither the weight or the length of the infant was significantly correlated with any maternal anthropometry measures at conception. However, the lack of significance may in part be due to the small sample size (N=28). The *trend* was for positive correlations between almost all maternal anthropometric measures and birth weight (e.g. for maternal weight, r=0.20; for maternal BMI, r=0.31; for triceps skinfold, r=0.24; for % body fat, r=0.35, p<0.05).

With maternal fat-free mass, however, there was virtually no association. For birth length, fairly strong associations were seen between maternal weight (r=0.19) and height (r=0.33). There was strikingly little association between any measures of maternal fatness or fat-free mass at conception with birth length.

Associations between infant size between 1 and 6 months and maternal size and body composition at 1 month postpartum are presented in Table 11.13. The larger cross-sectional group of women is used here as measures around the time of conception are not part of the analysis. Maternal weight, BMI and fat-free mass are now strong predictors of infant weight and

Table 11.14: Correlations between infant size at one to six months and maternal diet at conception.

	Infant Weight			Infant Length		
	Month 1	Month 3	Month 6	Month 1	Month 3	Month 6
Kcal/day	.09	-.15	-.15	-.16	-.08	-.08
Kcal/kg	-.19	-.22	-.27	-.28	-.21	-.24
Kcal from Animal	-.27	.20	.23	-.21	.25	.42*
% Kcal from Dairy	-.22	.16	.22	-.16	-.32+	.47*

+p<0.10, *p<0.05

Table 11.15: Correlations between infant size at one to six months and average maternal diet during pregnancy.

	Infant Weight			Infant Length		
	Month 1	Month 3	Month 6	Month 1	Month 3	Month 6
Kcal/day	-.04	-.14	-.03	-.17	-.04	-.01
Kcal/kg	-.08	-.24	-.20	-.20	-.15	-.23
Kcal from Animal	-.25	.13	.21	-.26	.17	.34+

+p<0.10, *p<0.05

length at all three time points. Surprisingly, correlations with maternal fatness are almost non-existent.

Maternal Diet and Infant Size

There was a tendency for women whose diets were of better quality at conception to have heavier, and certainly longer, infants at 3 and 6 months (Table 11.14). A similar pattern was seen for pregnancy, where again better quality diets predicted somewhat heavier, and significantly taller, infants at 3 and 6 months (Table 11.5).

Discussion

These analyses show that the course and outcome of pregnancy were dependent upon the health and nutritional status of the Solís women even before they became pregnant.

While women are usually advised to increase their energy intake during pregnancy, there is little evidence of such an increase in developed countries [1]. The Solís women consumed about 200 kcal/d more, but only in the last trimester. However, weight gains were considerably smaller than both recommendations and actual gains seen in wealthier countries. Despite this, the women on average gave birth to infants only slightly smaller than those of well-nourished women. However, their infants showed substantial growth failure starting about 3 months after birth, and this was worse if their mothers weighed less and had less lean tissue.

Heavier women at conception ate less, even on a body weight basis, than lighter women, but the quality of their diet was better. Those women who began pregnancy with smaller fat stores not only ate more, but also had greater weight gains during pregnancy. Despite their greater fat gain, the thinner women never exceeded the body fat of the heavier groups. Much of the weight gained was retained as maternal fat after the birth of the child. These low BMI women lost weight as a group during the early months of lactation.

The mothers who began pregnancy with greater fat stores subsequently lost some of those stores during pregnancy. They were able to redeposit some fat during early lactation. However, as a group the amount of fat mobilized during lactation by the Mexican women was small. Given the low gestational weight gains during pregnancy, the loss of fat stores very early in lactation, and the very early growth faltering of infants in this environment, there is need to further examine the relationship between maternal weight, and fat and lean mass, to infant growth. The degree to which suboptimal infant growth is related to nutrient transfer during pregnancy, to insufficient milk production or to breastmilk nutrient composition, is unclear.

Policy Implications

- In the Solís population pregnancy outcome is dependent upon maternal prepregnancy weight, so that it is necessary to focus on the nutritional status of women prior to pregnancy. This implies that interventions that affect maternal weight should be targetted to women both *before* and during pregnancy and lactation. Unless this is done, there are likely to be trans-generational effects of small maternal size, this is likely to be especially important in younger women with even lower BMI than the sample examined here.

- Even though thinner women gained substantially more weight in pregnancy than fatter women, they did not achieve the same fatness by parturition. They also ate less and lost less fat during lactation. Women who weighed less, had a lower BMI and less fat-free mass had infants with most growth-faltering. Thus, infant growth seems to depend on the overall *mass* of maternal tissue, and not her height, or her percent body fat. Again, this supports the evidence for trans-generational effects of small maternal size. In future research it is of urgent importance to understand the physiological basis for these inter-relationships. Perhaps heavier mothers, who *are* eating better quality diets in these communities, endow their fetus with better nutrient stores at birth. In the next chapter, we find that *both* maternal size and the quality of her diet predict infant size at 6 months. In any event, it is evident that maternal size and/or diet during pregnancy is a major factor affecting development of the infant during the first six months of life.

- As far as monitoring the risk of undernutrition in pregnancy and lactation is concerned, it is apparent from these analyses that it is inappropriate to use pregnancy weight gain as an indicator of maternal nutritional status and infant risk. This is not to say that low weight gain does not predict low birth weight. However, the *most* weight gain occurred in the thinnest women, whose infants became the most growth-stunted. This inverse relationship between maternal fatness and weight gain undoubtedly has some physiological basis, and nutrient intake cannot be *primarily* responsible.

- There is no evidence of dietary energy inadequacy in this population or in this sample of women; only two had a low BMI, skinfold thickness and percent body fat were high on average, and energy intake certainly increased very soon after parturition so that food must have been available. On the other hand, women who consumed diets poorer in quality during gestation gave birth to infants with greater growth-faltering during the first six months. Again, dietary quality seems to be the major problem.

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Chapter Twelve.
Feeding and Growth of Infants

The Importance of Infant Feeding Practices

There are many reasons why it is important to study and to understand infant feeding practices in developing countries. Primary among these is the need to ensure optimal nutrition for the young infant. Breast milk is theoretically the best food for infants, although in this population we have some concern that it may be inadequate in some nutrients such as water soluble vitamins (based on the high prevalence of vitamin B_{12} in milk discussed in Chapter Eight), vitamin A, or fat. If marginal malnutrition of the mother produces poor quality or quantity of breast milk, then earlier supplementation with nutrient-dense foods may benefit infant's growth and nutritional status. On the other hand, the *substitution* of breast milk by less nutritious liquids or foods can severely reduce the daily intake of nutrients.

A second general concern is the link between morbidity and infant feeding practices. Breast milk provides protection against morbidity through its content of multiple factors that improve the immune response of the infant and protect against attack by micro-organisms. In addition, feeding non-breast milk liquids and foods in this environment is certain to expose the infant to more pathogens in water, on food containers and utensils.

A third concern is the effect of prolonged lactation on the nutritional status of the mother. From Chapter Eight it appears, for example, that maternal vitamin B_{12} deficiency becomes more prevalent in lactation, presumably due to excretion of this vitamin in breast milk. Lactation may also lower maternal fat stores. Given the short inter-pregnancy interval in these women, with conception often starting during lactation (Chapter Ten), depletion of nutrients during lactation may lead to poor nutritional status prior to the onset of the next pregnancy.

Finally, it is apparent from the infant growth data (Chapter Five) that infancy is the age when growth-stunting begins and is most serious. This must be caused by one or more of the following: poor endowment of infant nutrient stores at birth; inadequate amounts of nutrient(s) in breast milk; substitution of breast milk by relatively non-nutritious foods; or high infant morbidity with subsequent poor appetite and/or poor absorption of nutrients.

The Mexico CRSP is rich in information with which we can attempt to explore these issues. The infants and their mothers were followed longitudinally from early in pregnancy through 8 months postpartum. There are data on infant intakes from non-breast milk foods for two days each month, although within the research design it was not possible to measure breast milk consumption. Data are available on infant and maternal morbidity from the weekly recalls; on infant growth, behavior and cognition (Chapter Thirteen); and other relevant maternal and environmental factors.

Postpartum Feeding Practices in the Solís Valley

Maternal Intake During the *Cuarentena*

The immediate post-partum period in the Solís Valley focuses attention on protecting the mother and her newborn from harmful physical and spiritual forces. As is characteristic throughout Latin America, the culture of reproduction is still influenced by the *cuarentena*, the forty day postpartum period during which the mother and infant are given special treatment and care. The *cuarentena* still exists in the communities judged by reported activities and food selection. However, early postpartum practices, particularly with respect to feeding, are relatively less ritualized than in many other areas. There are no strong prohibitions against feeding colostrum, nor are pre-lacteal purgatives a standard practice. "On demand" feeding begins at birth.

The cultural expectations pertaining to mothers and articulated by them in a pre-delivery interview focus more on food proscriptions than on food avoidances. As shown in Table 12.1 women intend to eat more chicken, pasta, and *atole* (a thick corn or rice-based drink), foods that are considered nutritious and strength-giving. Some women expressed concern about avoiding chili and pork in the early post-partum period.

The women also eat more food. Based on the longitudinal data in Chapter Eleven, mothers increase their energy intake early in lactation to an average of about 600 kcal/day higher than at conception.

Initiation of Breast-feeding and Supplements to Breast Milk

In the villages of the Solís Valley, the initiation of breast feeding is almost universal. Sevrage, or total weaning from the breast, generally occurs after the first birthday. In the preschooler sample of children followed between 18 and 30 months of age, 72% were weaned prior to 18 months of age and only 10% continued to be breast fed past their second birthday. Table 12.2 documents the fact that breast-feeding is normative in the villages. In the first month of life 98.9% of the infants in the sample received breast milk. The percentages drop slightly in subsequent months, but a very large majority of infants continues to receive breast milk throughout the first eight months.

Table 12.3 shows the first introduction of food by month of age. The first column is based on maternal report of any item containing calories, whereas the second column excludes teas, which are virtually always sweetened with small amounts of sugar. Sugar-sweetened herbal teas are commonly given to the infants, beginning in the first weeks of life. They may be given to

Table 12.1: Food prescriptions and proscriptions during the *cuarentena*, for most recent delivery (N=251).

Foods Avoided	%	Food Specially Consumed	%
Pork	21.0	"Cravings"	0.8
Spicy Foods	4.4	Chicken	74.5
Chile	29.7	Pasta	36.3
Pulque	3.2	*Pulque*	8.8
		Atole	41.4
		Chicken Consomme	16.3
		Tea	1.2

Table 12.2: Breastfeeding and breast milk supplements by age.

Age (months)	% Receiving Any Breast Milk		% Receiving Supplements to Breast Milk*	
	%	N	%	N
Birth - 1.0	98.9	93	6.4	6
1.0 - 2.0	97.9	92	14.2	13
2.0 - 3.0	96.5	83	22.9	19
3.0 - 4.0	94.8	73	26.0	19
4.0 - 5.0	93.2	68	32.3	22
5.0 - 6.0	92.2	71	60.1	43
6.0 - 7.0	90.9	70	61.4	43
7.0 - 8.0	88.2	67	74.6	50

* Excludes infants who are fully weaned from the breast

prevent illness and to comfort a crying baby, but are also given in response to illness, to ease symptoms or to effect a cure.

Some mothers begin to supplement breast milk at a very early age. In the first month of life, 7% of the infants were eating something in addition to breast milk. This increased to 14% in the second month and continued to rise with each additional month. By six months of age 60% of infants received food other than breastmilk. However, it is important to note that this figure is derived from the dietary intake records, which were collected for only two days per month. It

Table 12.3: Introduction of foods other than breast milk.

	Age at First Food*		Age at First Food Excluding Sweetened Tea	
Month	N	%	N	%
< 1	6	6.6	1	1.1
1	13	14.3	6	6.6
2	13	14.3	11	12.1
3	12	13.2	11	12.1
4	12	13.2	16	17.6
5	17	18.7	19	20.9
> 5	18	19.8	27	29.7

* Includes small amount of corn flour, rice flour or powdered milk

is probable that the percent is actually higher since it does not include foods given on days other than those for which dietary records were obtained, and, as described below, supplementary foods are not given every day to infants, even after the weaning process has begun.

General Pattern of Infant Feeding

Supplementation to breast milk occurs in a variety of forms, creating a complex pattern of alternatives when viewed from a community-wide perspective. Table 12.4 describes patterns of supplementation, categorized by the type of food infants are receiving. The most common pattern was to supplement breastmilk with other foods (especially cereals and fruits) but not with formula or other milk. Supplementing breast milk only with other milk and no other food was a rare occurrence. As infants get older, there is an increase in the number of mothers who followed another, alternative feeding strategy -- breastfeeding, milk and other food, but it was a less popular alternative than breastfeeding alone or breastfeeding and supplementing with other foods.

From the food intake data, collected 2 consecutive days each month, it is apparent that mothers shift back and forth between exclusive breast feeding and supplementation from one day to the next. For example, an infant may be reported to have received teas, milks or even other foods during the two days of intake measurement at two and three months of age, nothing during the monitored days in months four and five, then food again during months six to eight. This carries

Table 12.4: Patterns of infant breast milk supplementation.

Age (mo)	# with Diet Data	Breast Milk Only		Breastfed, Milk, and Other Food		Breastfed, Other Food (no milk) Only		Breastfed & Milk	
	N	N	%	N	%	N	%	N	%
0 - 1	94	87	92.6	1	1.1	4	4.3	1	1.1
1 - 2	94	79	84.0	2	2.1	10	10.6	1	1.1
2 - 3	86	64	74.4	3	3.5	16	18.6	0	0.0
3 - 4	77	54	70.1	3	3.9	13	16.9	3	3.9
4 - 5	73	46	63.0	5	6.8	17	23.3	0	0.0
5 - 6	77	28	36.4	7	9.1	35	45.4	1	1.3
6 - 7	77	27	35.1	11	14.3	32	41.6	0	0.0
7 - 8	76	17	22.4	9	11.8	40	52.6	1	1.3

the implication, often not recognized, that it is difficult to categorize the feeding pattern of an infant based on just a few days of intake information.

The Types of Food Fed to Infants

During the first 3 months after birth almost all the supplemental energy, which is very low (mean 17 kcal, median zero), comes from milks and sugar (Table 12.5). Between months 3 and 6 mean intake increases to 44 kcal (although the median is only 2 kcal) with most of the energy still provided as sugar and milk, but now often mixed with cereal; small amounts of maize or rice are ground and mixed with water or milk, and sugar, to make *atole*. Some mothers purchased packets of dry prepared rice or corn mix, fortified with iron, while others used home-prepared *masa* or rice. Pasta, from household meals, is now fed to some infants.

Between 6 and 8 months the median intake is still only 37 kcal/day, with the average somewhat increased to 95 kcal per day. About half of this energy is still from sugar and milk, with some *tortillas* now fed (although not to most infants) and slightly more cereal.

In summary, the general picture in the Solís Valley is for some infants (the minority until after 5 months of age) to be supplemented with relatively small quantities of supplemental milk and sugar, with very small amounts of cereal or maize added in increasing amounts after 3 months. Apart from pasta from family meals, and occasional bananas, few other foods are provided to the infants.

Table 12.5: Intake of nutrients and foods during infancy.

	Mean	Median	Minimum	Maximum
0-3 Months				
Total kcal	17	0	0	351
Animal kcal	13	0	0	455
Sugar kcal	5	0	0	115
Milk kcal	10	0	0	341
Tortilla kcal[1]	0	0	0	0
3-6 Months				
Total kcal	44	2	0	774
Animal kcal	22	0	0	447
Sugar kcal	11	0	0	259
Milk kcal	20	0	0	447
Tortilla kcal[1]	2	0	0	84
Masa kcal	1	0	0	54
Rice flour kcal	1	0	0	34
Pasta kcal	4	0	0	48
6-8 Months				
Total kcal	95	37	0	773
Animal kcal	37	3	0	630
Sugar kcal	15	0	0	165
Milk kcal	30	0	0	630
Tortilla kcal	13	0	0	196
Masa kcal	2	0	0	81
Rice flour kcal	2	0	0	91
Pasta kcal	4	0	0	48

Which Mothers Supplement Their Infant?

The intake of foods listed in Table 12.5 was not related to household wealth (MSL or house score) or the number of people in the househ 'ld, in any of the three age periods. Ownership of a larger amount of land was associated with infants receiving less sugar from 0-3 months and 3-6 months.

Between 0 and 3 months, the only significant relationship (Spearman's correlations) was that between infant's sugar intake and sanitation of the inside of the home ($r=0.34$, $p<0.05$) and appearance of the mother ($r=0.30$, $p<0.08$). Between 4 and 6 months, however, a number of household variables predicted foods fed to the infant. Cleaner appearance of the preschooler, mother and the yard of the house (proxies for maternal management) characterized mothers who supplemented their infant with more energy from milk and cereals. Together these results suggest a tendency for more "organized" mothers to give more non-breast milk foods to their infants. Between 7 and 8 months of age, when the majority is receiving some supplementation to breast milk, there were no significant relationships between feeding practices and these social variables.

Summary of infant feeding practices.

Bottles are readily available for purchase in the municipal center of Temascalcingo, and powdered milk formula is a ubiquitous, if expensive, commercial item. However, the use of bottles and breast milk substitutes presents a more complex picture than a simple choice between "breast versus bottle." Bottles and infant formula are part of the infant feeding strategies of many households, but women almost universally initiate breastfeeding and the majority maintain it for many months.

Undoubtedly there are a number of explanations for the maintenance of breast feeding in an environment that might well be expected to show sharply declining rates of breast feeding. One possibility is the role of delivery practices and home births; 59% of the mothers delivered in the Solís clinic and 37% in their homes. Thus, the potentially adverse influence of more "modern" hospital practices was not present.

The international public health community has placed a strong emphasis on promoting "exclusive breast feeding" in the first four months of life. Arriving at an operational definition of "exclusive breast feeding" has been a source of some confusion and debate. Even in the communities of the Solís Valley, where breast milk is a primary source of nutrition for infants, more than 60% receive other foods before 5 months of age. Here, as in many other parts of the world, mothers give their infants herbal teas, to which small amounts of refined sugar are added. Even excluding the teas, nearly 50% of children received supplements to breast milk in the first four months. Nevertheless, on average the amount of supplement given (kcal content) was very small.

The common pattern of alternating days of exclusive breast feeding with days in which infants receive supplementation suggests that most mothers view breast milk as the dietary mainstay of infant nutrition and the use of other foods can be quite erratic.

The positive associations between variables marking maternal organization/management and the amount of supplementation given to infants between four and six months of age suggest that women view the preparation and feeding of supplementary foods to infants as a desirable behavior and as part of the definition of effective domestic management. However, further ethnographic study is necessary to determine the extent to which cultural beliefs, as contrasted with situational constraints and conditions, affect the nature of supplementation practices.

It is important to note that infant feeding practices were not associated with the wealth of the household. This means, on the one hand, that wealthier mothers did not perceive the necessity of purchasing milks and other supplemental foods for their infants. On the other hand, poorer mothers did not feed less animal products to their infants. This is perhaps not surprising as the total intake of foods other than breast milk was quite small and not likely to be constrained by wealth.

Is Infant Morbidity Related to Infant Feeding Practices?

The number of reported morbidity episodes was low as is usually the case in early infancy especially when breastfeeding predominates. Thirty percent had no reported illness during the first 6 months. On average they suffered two illness episodes, but only 32% suffered from diarrhea between birth and 8 months, 17% had an occurrence of fever, 40% a lower respiratory problem and 9% an upper respiratory illness. Some short-term illnesses would have been missed because of the inability of mothers to recall these over a week-long period (Chapter Nine).

Perhaps in part due to the low reported incidence of illness in these infants, there was no evidence that feeding practices influenced infant morbidity; there were no significant correlations between individual children's food intake variables and their morbidity in any period.

Do Infant Feeding Practices Affect Growth?

Analyses were undertaken to determine whether supplemental foods explain the growth-faltering of the Solís infants. Because foods are fed in combinations, it is difficult to attribute any nutritional outcome, such as growth, to a single food (also see Chapter Six). Also, the amount and frequency of feeding individual foods was small. For these reasons, the combinations of foods fed between 3 and 6 months were examined using factor analysis. Four factors were identified in this manner. Factor One comprised sugar, *masa*, milk and teas, and was labelled "*masa atole*". Factor Two was legumes, vegetables, other foods, pasta and meat, indicating foods that were portions of "household meals" fed to the infant. Factor Three was predominantly fruit, with some vegetables and eggs, called "fruit and eggs". Factor Four was predominantly rice flour, with some sugar and eggs, indicating "rice *atole*".

These factors were compared, using Spearman's rank correlations, to the rates of weight and length gain of the infants at intervals between birth and 8 months of age. (The actual growth variables were residual weight and length over the period after controlling for 3 month weight and length respectively). Growth in weight between 6 and 8 months was weakly negatively related ($r=-0.21$, $p<0.06$) to *masa atole* intake, but the relationship between 3 and 8 months or 3 and 6 months did not reach significance. Weight growth from 1 - 8 months was negatively related ($r=-0.25$, $p<0.05$) to rice *atole* intake, but as the relationship was not significant between 3 and 8 months this is probably not important.

As far as rate of length growth is concerned, children who consumed more rice *atole*, and perhaps corn *atole*, grew more slowly between 3 and 6 months ($r=-0.28$, $p<0.01$) and 3 and 8 months ($r=-0.36$, $p<0.001$). Those fed more "fruit and eggs" grew slightly better between 3 and 8 months ($r=0.21$, $p=0.06$). No other significant relationships were found. These results could be interpreted as meaning that feeding *atole* had a negative impact on infant growth. However, it must be remembered that most infants consumed no *atole*; for example, only one third were reportedly fed *atole* between 3 and 8 months. Also, the amounts fed were small. The negative relationship between *atole* and growth illustrates a tendency, in the case of the minority who were fed *atole*, for a greater quantity of *atole* to be associated with slower growth. However, many infants who were not reported as eating *atole* grew more poorly than those who did.

In summary, the reported quantity of supplemental foods fed to these infants is so low, and growth stunting is so universal (Chapter Five) that it is difficult to attribute the growth-failure to specific feeding practices or foods. The Nutrition CRSP was not designed with the expectation that growth failure would be so predominant early in infancy. A food frequency record rather than measurement of supplemental foods two days per month would probably have provided a better indicator of usual intakes. Ideally, breast milk intakes and composition should also be measured to address the issue of whether foods substituted for, or added to, nutrients consumed in breast milk. At this point we conclude from our data that infant size at birth, and maternal size are much stronger predictors of infant growth failure than are morbidity and supplemental feeding practices.

Chapter Thirteen provides information on the effect of supplemental foods on behavioral and cognitive development of these infants. In general, more supplementation was associated with *better* cognitive and behavioral development.

Multiple Regression Models to Predict Infant Growth

Infant growth can be affected by many other factors in addition to their feeding practices. For example, from Chapter Eleven we know that maternal body composition is a strong predictor of infant size and growth. In Chapter Five we saw the strong relationship of the infant's size at birth on size at 6 and 8 months. Morbidity and the household environment may also have an influence. Because of these potential multiple associations we turned to multiple regression models where the effects of all these factors could be examined simultaneously. They also permit assessment of whether maternal effects operate through environmental rather than biological variables; for example, children may be fed differently, or live in better environments, if their mothers are fatter. These multiple regression analyses have been published elsewhere [1].

The models used 88 of the infant-mother pairs who had virtually complete measurements for all variables. Infant weight, length and weight/length values were transformed to Z scores to correct for any differences in the age when data were collected, so that size and growth could be compared among infants at birth, 3, 6 and 8 months. Infant anthropometry measures were used if taken within $\pm$ 14 days of 3,6 or 8 months [Two other approaches were attempted to estimate the size of the infant at exactly 3, 6 and 8 months. The first was a linear regression of each measure against age between birth and 8 months. Because the regressions for many individual infants were highly non-linear this method was not used in analyses. The second was a quasi-cubic hermite spline interpolation of size against age; this method allowed excellent fit of each child's data points, and may be used in future analyses]. Maternal anthropometric measures used were those closest to these same time periods. Women's fatness was calculated from skinfold thickness at four sites by the method of Durnin and Womersley (Chapter Eleven).

Linear models (PROC GLM, MANOVA and SYSREG) were constructed for each time period on a theoretical basis to predict infant measures of *attained size* or *growth.* Interdependent variables were weight or length at birth, illness variables, total energy intake and energy from animal products. SES and household variables, and maternal size were used as independent predictors. These were entered into the models systematically to determine which models had most power and robustness. Maternal size (weight, height or weight/height) was always included as an independent variable because of its known strong influence on infant size in this population.

The models for predicting *birth weight* tested socioeconomic status (SES, an average of the material wealth and house quality scores), parity, and maternal age and anthropometry. Only mother's weight, height or weight/height were significant ($p<0.05$) with 12, 5 and 15% of the total variance explained respectively. In similar models for *birth length* maternal weight was significant with at most 20% of the total variance in birth length explained.

The *weight Z-score at 8 months* was tested against birth weight, 0-8 month average values for infant's illness and dietary variables, SES, and maternal size. Significant predictors were birth weight ($p<0.01$), energy from animal products (negative, $p<0.05$), and SES ($p<0.001$) with weight ($p<0.001$), maternal weight/height ($p<0.001$) and height ($p<0.06$). Table 12.6 shows

Table 12.6: Typical model predicting infant weight Z-score at eight months of age.

PROC GLM
Dependent Variable: Weight Z-score at 8 months
Model R^2: 0.36. N=63

Variables	DF	Type I SS	F Value	PR > F
Birth Weight	1	5.72	7.51	0.008
Average Illness	1	1.80	2.36	0.130
Average kcal	1	0.48	0.63	0.431
Animal kcal*	1	3.57	4.68	0.035
SES	1	2.52	3.30	0.001
Maternal Wt.	1	9.48	12.43	0.001

* Animal kcal was the only negative predictor. Removing average kcal from the model did not change the sign or the level of significance.

the model using maternal weight, which similar to the one using weight/height, predicted 36% of the variance in infant weight at 8 months. The negative association with animal products reflects the use of milk in *atole* - associations with cereal intake were not tested.

In similar models predicting the *length Z-score at 8 months* birth weight was replaced by birth length. A total of 45% of the variance in infant length at 8 months was predicted, with significant variables being birth length ($p<0.001$), average total illness (surprisingly positively, $p<0.03$), animal product intake (weakly negative, $p<0.08$), and maternal weight which was the strongest predictor even after the other variables had been entered ($p<0.0005$). With maternal length replacing weight, animal product intake lost its significance and 39% of total variance was explained. Using maternal weight/height the model explained 42% of the variance, with birth length and mother's weight/height as the strongest predictors and total illness and SES entering positively ($p<0.05$).

The average *rate of infant weight gain* between birth and 8 months was predicted by maternal weight ($p<0.01$, model R^2 20%) or weight/height ($p<0.01$, model R^2 19%) but not by her stature. During 0-3 and 3-6 months no variable predicted weight gain and the model predicted at most 10% of the variance. Between 6 and 8 months only total energy intake was weakly significant ($p<0.09$, model R^2 9%).

Using a similar model for the overall *rate of length gain*, the only significant variable was mother's weight ($p<0.01$), weight/height ($p<0.03$) or height ($p<0.01$) with models explaining 24-28% of the variance. Between 0 and 3 months, birth length was a strong predictor of length gain ($p<0.0001$) with no other variables entering significantly. The model using height as the index of maternal size explained 42% of the variance in length gain during 0 to 3 months. Replacing maternal height with weight/height and weight in the same model increased the variance explained to 46% and 54% respectively. Between 3 and 6 months, maternal weight, weight/height or weight were the only significant predictors of length increase and only a maximum of 17% of the variance could be explained. Between 6 and 8 months only total energy intake entered weakly and positively, no maternal size variable was significant (although weight/height was weakly significant, $p<0.08$), and a maximum of 21% of the variance was explained.

Summary of Infant Growth Predictors

Somewhat surprisingly, given the high prevalence of growth-faltering in the Solís infants, the social, illness, dietary, sanitation or other environmental variables did not explain any significant amount of variance in infant size or growth during the first 8 months of life. Maternal size was usually significant after these variables were included. Maternal weight and weight/height, rather than height, predict weight at birth and the rate of weight gain from 0 to 8 months, suggesting that maternal size (here, lean body mass specifically), and associated better quality maternal diet, are more important than height.

Policy Implications

- In these communities mothers are predominantly breast feeding their infants, even at 8 months postpartum.

- There is very little use of commercial formulas or milk. When milk is given it is usually mixed with sugar, irregularly, and in small amounts. Thus, good quality weaning foods are not available, or at least are not used, in these communities.

- The predominant weaning food is *atole*, a drink made with rice or corn. The data suggest that feeding more *atole*, which usually occurs after three months of age, is linked with growth-faltering. However, the majority of infants were not reported *atole* consumers and yet they still failed to grow normally. Additional studies of these relationships are needed urgently, including more frequent measures of both supplemental foods and breast milk.

- *Atole* may provide a way of increasing the micronutrient intake of infants, if it is enriched with appropriate minerals and vitamins. This is an important intervention that should be tested.

- Morbidity of these infants is low and does not explain growth-faltering. It is unlikely that measures to reduce infant morbidity in this population will prevent growth-faltering. We found no evidence that supplementing infants increases their chance of having clinical symptoms of illness.

- The best predictor of birth weight and birth length is maternal weight or weight-for-height; larger women also consumed better quality diets. This argues for more attention to the nutritional status of women.

- Maternal weight or weight-for-height also predicts infant weight gain between birth and 8 months and weight at 8 months. Either heavier mothers (who eat better quality diets) endow their infants with more nutrient stores at birth, or their breast milk quality is better.

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Chapter Thirteen.
Predictors of Neonatal Behavior, Mother-Infant Interaction, and Infant Motor and Mental Performance

Introduction

The first six months of life represent a period of extraordinary physical and psychological growth. During this important period, children develop in ways that provide bases for future learning, the establishment and maintenance of social relationships, and cognitive processes that govern future interactions with the larger environment. Malnutrition may be a major barrier to the optimal development of Third World children. Anecdotal evidence has long linked behavioral and cognitive effects to severe malnutrition.

Given the higher prevalence of mild-to-moderate malnutrition in the less developed countries, the effects of this type of malnutrition on behavior and cognitive function have the potential to be a far greater social problem than the more dramatic effects of marasmus and kwashiorkor. Unfortunately, the relationship of mild-to-moderate malnutrition to the behavior and cognition of children is less than clear [1]. This is due in part to the close associations between poverty, malnutrition, and psychological performance and behavior. In this chapter, we focus on the cognition and behavior of Mexico Nutrition CRSP infants. As this is a period of growth faltering (Chapters Five and Twelve), it is important to determine the degree to which this period is associated with behavioral and cognitive performance.

Assessing Infant Cognition and Behavior: Univariate Statistics

A number of techniques, approaches, and instruments have been developed to assess infant behavior and psychological and motor development. The Mexico CRSP conducted examinations of target infants at three points in time: shortly after birth, and at 3 and 6 months. Described below are abbreviated descriptions of the research instruments. Chapter Two provides additional information concerning the administration and composition of these psychological examinations.

The Brazelton Neonatal Behavioral Assessment Scale

Shortly after birth, infants were examined using the Brazelton Neonatal Behavioral Assessment Scale (NBAS). The NBAS is an approach developed by Dr. T. Berry Brazelton to

> "describe autonomic, motor, state and social attention systems -- which were seen as integrative and interacting with each other in the normal, healthy, full-term infant...We conceived of a single assessment in the neonatal period as only a brief glimpse into the continuum of the infant's adjustment to labor, delivery, and his new environment. As such, it is expected to reflect his inborn characteristics and behavioral responses that had already been shaped by the intrauterine environment"[2].

The results presented in this chapter are for a sub-sample of 49 newborns on whom NBAS were conducted within 7 days of birth (after the elimination of a pair of twins). Eighty-six percent of the these NBAS measures were taken within 2 days of birth. As is typical, the BNAS, the 49 items were used to create seven scales: six behavior clusters and one reflex cluster. These are described by Brazelton et al:

> "*Habituation* is the process of reactivity followed by response inhibition during sleep. *Orientation* includes the ability to attend to visual and auditory stimuli and the quality of the states of alertness. The *motor cluster* measures motor performance and the quality of movement and tone...*Range of state* is a measure of arousal level, or arousability. *Regulation of state* is how the infant responds when aroused, which may consists of endogamous mechanisms for lowering arousal or the ability to respond to environmental (examiner-induced) input. The *autonomic* cluster records signs of stress related to homeostatic adjustments of the nervous system. The *reflex* cluster is a simple count of the number of abnormal reflexes [1]."

Table 13.1 shows the distribution of the seven Brazelton cluster scores.

Mother-Infant Interaction

At the ages of 3 and 6 months, the interaction of the infant with its mother was observed (see Chapter Two). The observations were done by a trained psychologist in the infant's home. For each of 30 observation periods, the presence or absence of nine infant behaviors was coded: 1) *looking at the mother*, 2) *smiling*, 3) *cooing or vocalizing*, 4) *laughing*, 5) *yawning*, 6) *knits brow*, 7) *fussing*, 8) *bicycling limbs*, 9) and *squirming*. Similarly, eight maternal behaviors were coded. In the interests of brevity, the analyses presented in this chapter omit the maternal behaviors while recognizing the synergistic nature of maternal and infant behavior.

Table 13.1: Distribution of NBAS a priori scores (N= 49).

Potential scores range from 1 to 9:

	Mean	SD	Q1	Median	Q3
Habituation	6.2	1.24	5.3	6.2	7.0
Orientation	4.0	1.60	2.8	3.8	5.3
Motor Performance	4.5	0.93	4.0	4.6	5.2
Range of State	4.0	0.91	3.2	4.2	4.8
Regulation of State	6.2	1.06	5.3	6.2	7.0
Autonomic Regulation	5.8	1.12	5.0	6.0	6.7
Reflexes*	1.7	1.22	1.0	2.0	2.0

* Low score is best.

At six months, an additional set of mother-infant characteristics was measured by observer *ratings* of overall behavior, rather than as a proportion of several observations. For the infant, these were ratings of agitated/relaxed physical behavior, averting of face, looking at mother, facial expressions, agitation, and vocalizations. As above, the maternal ratings are omitted from these analyses due to space restrictions.

The current analyses are for 86 infants with mother-infant data at 3 and 6 months. Table 13.2 shows the distribution of the 9 infant variables. At 3 months, the commonest infant behaviors at this age were *moving limbs*, *looking at the mother*, and *vocalizing*, while the least frequently observed infant behaviors were *laughing*, *yawning*, and *brow-knitting*. At 6 months, the most frequently observed infant behaviors were *moving limbs*, *looks at mother*, *coos/vocalizes*, and *smiles*. The least frequent infant behaviors were *laughs*, *yawns*, and *knits brow*. For 85 infants at six months, the modal ratings were *predominantly alert*, *occasional agitated movement*, *frequently averts face*, *rarely looks at mother*, *little facial expression*, *occasionally agitated*, and *does not vocalize* (Table 13.3).

The Bayley Scales of Infant Development at 6 Months

As described in Chapter Two, the Bayley scales of infant development are a structured assessment of an infant's mental and behavioral growth. Children are presented with a series of situations and are assessed on their performance with respect to a series of behaviors. This series of 'items' is then used to create two scores:

Table 13.2: Distribution of mother-infant interaction variables at 3 and 6 months (N=86).

	% > Zero	Q1	Median	Q3
3 Months				
Moves Limbs	80.5	3.3	20.0	50.0
Looks at Mother	78.2	3.3	20.0	66.7
Coos/vocalizes	77.0	3.3	10.0	28.0
Smiles	60.9	0.0	5.8	20.0
Squirms	47.7	0.0	0.0	13.3
Fusses	42.5	0.0	0.0	10.0
Knits Brow	27.6	0.0	0.0	3.3
Yawns	23.0	0.0	0.0	0.0
Laughs	9.2	0.0	0.0	0.0
6 Months				
Moves Limbs	80.5	3.3	20.0	50.0
Looks at Mother	78.2	3.3	20.0	66.7
Coos/vocalizes	77.0	3.3	10.0	28.0
Smiles	60.9	0.0	5.8	20.0
Squirms	47.7	0.0	0.0	13.3
Fusses	42.5	0.0	0.0	10.0
Knits Brow	27.6	0.0	0.0	3.3
Yawns	23.0	0.0	0.0	0.0
Laughs	9.2	0.0	0.0	0.0

- The *mental* scale is "designed to assess sensory-perceptual acuities, discriminations and the ability to respond to these; the early acquisition of 'object constancy' and memory, learning and problem solving ability; vocalizations and the beginnings of verbal communication and early evidence of the ability to form generalizations and classifications, which is the basis for abstract thinking" [3]. Two different mental measures were employed by the Mexico CRSP: 1) the number of the highest mental item passed, and 2) the percent of mental items passed.

- The *motor* scale provides "a measure of the degree of control of the body, coordination of the large muscles and finer manipulatory skills of the hands and fingers. As the Motor Scale is specifically directed towards behaviors reflecting motor coordination and skills, it is not concerned with functions that are commonly thought of as 'mental' or 'intelligent' in nature" [3]. As with the mental items, two motor measures were

Table 13.3: Distribution of infant interaction ratings (N=85).

General State	Predominantly drowsy	2.4
	Somewhat drowsy	1.2
	Predominantly alert	96.5
Agitated Movement	Frequent agitated movement	16.5
	Occasional agitated movement	50.2
	Relaxed body	32.9
Averts Face	Frequently averts face	69.4
	Occasionally averts face	27.1
	Rarely averts face	3.5
Looks at Mother	Rarely looks at mother	58.8
	Sometimes looks at mother	30.6
	Frequently looks at mother	10.6
Facial Expression	Frequently pouts	22.4
	Little expression	55.3
	Smiles frequently	22.4
Agitation	Frequently agitated	22.4
	Occasionally agitated	44.7
	Is not agitated	32.9
Vocalizes	Does not vocalize	82.4
	Sometimes vocalizes	14.1
	Makes various vocal sounds	3.5

employed by the Mexico CRSP: 1) the number of the highest motor item passed, and 2) the percent of motor items passed.

In addition to the *motor* and *mental* scores, Mexico CRSP psychologists administered the Bayley *Infant Behavior Record*, which is the examiner's judgements (on five or nine point scales) concerning the infant's: 1) *object orientation* (happiness/unhappiness during throughout testing), 2) *goal directedness* (sustained efforts to attain an object of interest), 3) *attention span* (continued interest in a toy, person, or situation), 4) *reactivity* (alert and aware of surroundings), 5) *gross motor coordination* (smooth vs poor), 6) *fine motor coordination* (smooth vs poor) 8) social *orientation* (avoiding vs friendly), 9) *cooperativeness*, and 10) *general emotional tone* (unhappy

Table 13.4: Descriptive statistics for Bayley measures.

	Mean	SD	Q1	Median	Q3
Mental Score					
Highest Item Passed	75.8	10.43	69.0	80.0	84.0
% of Items Passed	43.3	17.43	29.4	45.1	56.9
Motor Score					
Highest Item Passed	32.1	6.03	27.0	33.0	37.0
% of Items Passed	44.9	18.98	26.9	46.2	57.7
Infant Behavior Record					
Object Orientation	5.0	1.79	3.0	5.0	6.0
Goal Directedness	4.1	1.49	3.0	4.0	5.0
Attention Span	4.4	1.37	3.0	4.0	5.0
Reactivity	5.0	1.17	4.0	5.0	5.0
Gross Motor Coordination	3.2	0.93	3.0	3.0	4.0
Fine Motor Coordination	3.0	0.78	3.0	3.0	3.0
Total Cognitive Factor	24.6	6.07	20.0	25.0	29.0
Social Orientation	3.3	0.70	3.0	3.0	4.0
Cooperativeness	5.5	1.24	5.0	6.0	6.0
General Emotional Tone	4.9	1.46	4.0	5.0	6.0
Total Extraversion Factor	13.6	3.04	12.0	14.0	16.0

vs happy). In addition, two summary variables are included: 1) *total cognitive factor*, and 2) total *extraversion factor*. Table 13.4 provides the descriptive statistics for these variables.

Infant Anthropometry and Infant Psychology

The following section focuses on the relationship between infant size and infant psychological performance and behavior. As infancy is a time of enormous growth faltering (Chapter Five), this section is particularly significant to the extent to which growth faltering and infant behavior and psychological performance may be linked.

Brazelton Scores

Table 13.5 shows the Pearson correlations between the Brazelton scores and infant anthropometry at birth. In general, there is little relationship between newborn anthropometry and the NBAS clusters. One exception is the *reflex* score. Curiously, more abnormal reflexes are associated with longer babies. The other exception is *autonomic stability*, physical signs of

Table 13.5: Pearson correlations between NBAS cluster scores and infant anthropometry at birth (N=44).

	Weight	Length	Wt/Lth	Ponderal Index	Head Circum
Habituation	-0.14	0.01	-0.19	-0.18	0.03
Orientation	-0.22	-0.12	-0.22	-0.09	-0.17
Motor	-0.06	-0.02	-0.07	-0.05	-0.01
Range of State	0.02	0.07	-0.01	-0.07	-0.14
Regulation of State	0.09	-0.01	0.11	0.11	0.03
Autonomic Stability	0.27*	0.20	0.23	0.05	0.30*
Reflexes	0.20	0.28*	0.12	-0.13	0.08

* $p < .10$

Table 13.6: Spearman correlations of infant size with infant interaction variables (3 mo).

	N	Moves limbs	Looks at Mother	Coos	Smiles	Squirms	Fusses	Knits Brow	Yawns	Laughs
At Birth										
Birth Weight	72	-0.20*	0.00	-0.01	0.20*	-0.11	0.06	-0.26†	0.05	0.02
Birth Length	63	-0.05	-0.05	0.25†	0.14	0.01	0.08	-0.14	-0.03	0.01
Weight/Lgth³	63	-0.16	-0.05	-0.30†	0.01	-0.07	-0.06	-0.13	-0.05	-0.10
Head Circ	44	-0.21	0.08	0.20	0.18	-0.18	0.04	-0.41‡	-0.20	0.04
At 3 mo										
Weight	73	-0.07	-0.03	0.19	0.25†	-0.17	-0.05	-0.14	-0.29†	-0.19
Length	73	-0.09	-0.14	0.07	0.31‡	-0.11	-0.07	-0.26†	-0.17	0.16
Weight/Lgth³	73	-0.08	0.06	0.12	-0.09	-0.08	0.04	0.14	-0.27†	0.08
Head Circ	73	-0.01	-0.09	0.09	0.28†	-0.00	0.10	-0.19	-0.14	0.12
Growth rates										
Weight (0-3 mo)	63	0.03	-0.09	0.24*	0.20	-0.14	-0.12	0.04	-0.31†	0.16
Length (0-3 mo)	57	-0.01	-0.01	-0.14	0.23*	-0.12	-0.13	-0.10	0.06	0.19

* $p < 0.10$ † $p < 0.05$ ‡ $p < 0.01$

stress (startle response, tremors, and changes in skin color) being associated with lighter babies and those with smaller head circumferences.

Mother-Infant Interaction at 3 Months

Table 13.6 shows the Spearman's correlations between infant anthropometry and the infant behaviors at 3 months. Heavier infants at birth tended to show less moving of limbs ($r=-0.20$, $p<0.10$, $N=72$), more smiling ($r=0.20$, $p<0.10$, $N=72$), and less knitting of the brow ($r=-0.26$, $p<0.05$, $N=72$). Also, longer infants at birth cooed somewhat more at 3 mo ($r=0.25$, $p<0.05$, $N=63$), while fatter newborns (weight/length^3) were less likely to coo ($r=-0.30$, $p<0.05$, $N=63$). Newborns with larger head circumferences showed less knitting of the brow at 3 months ($r=-0.41$, $p<0.01$, $N=44$).

Infant anthropometric measures at 3 months show infants who smiled more tending to be heavier (*weight Z-score*: $r=0.25$, $p<0.05$, $N=73$), longer (*length Z-score*: $r=0.32$, $p<0.01$, $N=73$), and with larger head circumferences ($r=0.28$, $p<0.05$, $N=73$). Infants who yawned more tended to be lighter (*weight Z-score*: $r=-0.29$, $p<0.05$, $N=73$), and thinner (*weight/length^3*: $r=-0.27$, $p<0.05$, $N=73$) than infants who yawned less, while longer infants at 3 mo were less likely to knit their brow ($r=-0.26$, $p<0.05$, $N=73$). Faster weight growth between birth and 3 months was associated with more cooing ($r=0.24$, $p<0.10$, $N=63$), and less yawning ($r=-0.31$, $p<0.05$, $N=63$), while faster length growth was associated with more smiling at 3 mo ($r=0.23$, $p<0.10$, $N=57$).

Mother-Infant Interaction at 6 Months

Observations

Infant interaction variables at 6 months showed little or no relationship with infant size at birth or 3 months. The only exceptions are positive correlations between the amount of infant smiling and length ($r=0.24$, $p<0.05$, $N=73$) and length Z-score ($r=0.22$, $p<0.10$, $N=73$) at 3 months. Longer infants at 6 months also smiled more ($r=0.22$, $p<0.10$, $N=60$), laughed more ($r=0.25$, $p<0.10$, $N=60$), and yawned more ($r=.30$, $p<0.05$, $N=60$). The ponderal index at 6 months was associated with less yawning ($r=0.24$, $p<0.10$, $N=59$), and larger head circumferences were associated with somewhat more squirming ($r=0.22$, $p<0.10$, $N=60$). Rates of growth showed little relationship to infant behaviors.

Ratings

Infant interaction ratings at 6 months showed agitated movement to be more common among infants who at birth were heavier (*Kendall's tau-b*$=-0.25$, $p<0.05$, $N=72$), longer (*tau-b*$=-0.30$, $p<0.05$, $N=70$), and with larger head circumferences (*tau-b*$=-0.30$, $p<0.05$, $N=45$).

More agitated movement was also seen in infants who were longer at 6 months (*tau-b*=-0.26, $p<0.05$, N=61). Those infants rated as more vocal at 6 months tended to be lighter at birth (*tau-b*=-0.22, $p<0.10$, N=72) and longer at 3 months (*tau-b*=-0.24, $p<0.04$, N=73) and 6 months (*length Z-score*: *tau-b*=-0.29, $p<0.05$, N=73).

Infants who were rated as more frequently looking at the mother at 6 months tended to be heavier at 3 months (*tau-b*=0.21, $p<0.05$, N=72) and 6 months (*tau-b*=0.17, $p<0.10$, N=72), and longer at 3 months (*tau-b*=0.18, $p<0.10$, N=72) and at 6 months (*tau-b*=0.17, $p<0.10$, N=72). Those infants who were rated having a relaxed body at 6 months tended to be lighter (*tau-b*=-0.19, $p<0.05$, N=70), shorter (*tau-b*=-0.24, $p<0.05$, N=63), and have smaller head circumferences at birth (*tau-b*=-0.24, $p<0.10$, N=44). These children also tended to be shorter at 6 months (*tau-b*=-0.21, $p<0.05$; N=60) and have had slower length growth between 3 and 6 months (*tau-b*=-0.28, $p<0.05$, N=52). Infants who were rated as being more vocal at 6 months tended to have had lower birth weights (*tau-b*=-0.18, $p<0.10$, N=73) and were shorter at 3 months (*tau-b*=-0.20, $p<0.05$, N=72).

Bayley Scores at Months

Tables 13.7-13.9 provide the Spearman correlations between the Bayley scores and infant anthropometry. *Mental* and *motor* scores have sizeable correlations with birth weight, heavier infants performing better on both measures at 6 months. Similarly, heavier and taller children at 3 months performed better on the mental and motor scores at 6 months. However, size at 6 months had a less clear relationship with the motor and mental scores, the only correlation significant at $p<0.10$ being between length and the highest item passed on the motor score. Growth rates showed little relationship to motor and mental performance at 6 months.

Several items on the Infant Behavior Record had sizeable correlations with infant anthropometry. Children who appeared to be happy throughout the test period (*object orientation*) tended to have heavier birth weights and larger head circumferences. Better fine motor performance was associated with heavier and fatter infants at birth, longer babies at 3 and 6 months, and faster length growth during 0-3 and 0-6 months. Social orientation had several moderate to large correlations with infant anthropometry: infants who were avoiding or withdrawn tended to be small in weight and length at 3 months and especially at 6 months. These withdrawn babies also tended to grow less quickly in weight and length from 0-6 months, and length during 3-6 months. Similarly, the general emotional tone of these infants tended to be worse for shorter children at 6 months.

Summary: Effects of Infant Anthropometry

Correlation analyses show infant size to be associated with infant behavioral and cognitive performance. In general, there is little relationship between Brazelton scores and infant anthropometry at birth, although lower birth weight babies showed more startle response, tremors, and changes in skin color. However, the infant interaction variables show a general pattern of larger infants smiling more, looking at the mother more, being more vocal, and yawning and knitting brow less. Larger babies also appeared to be *more* agitated, and to have a *less* relaxed body. This might be due to smaller children being more passive in their behavior. The Bayley motor and mental scores at 6 months also have sizeable associations with infant size at birth, larger infants performing better on both the mental and motor dimensions. The Infant Behavior Record variables show affirm the infant interaction results showing happier affect to be associated with larger infants at birth, and withdrawn babies to be of smaller size at 3 and 6 months. These results show the growth stunting of infants that occurs during this period to be associated with decreased behavioral and cognitive performance.

Maternal Anthropometry and Infant Psychology

The mother is the sole source of nutrients for most infants until the age of at least 3 months, and is a major source of nutrients for most infants for much longer (Chapter Eleven). As a result, deficiencies in infant psychological and physical performance during the first few months of life might reasonably be expected to be the result of deficiencies in maternal nutritional status.

Maternal anthropometry, and changes in maternal anthropometry during pregnancy and lactation, reflects aspects of maternal nutritional status, often in a very general way. This section focuses on the relationship of maternal anthropometry to the infant psychology measures. A more sophisticated appreciation of the results presented in this section would be aided by a careful reading of Chapter Eleven, which describes changes in maternal anthropometry during pregnancy and lactation.

Maternal anthropometry was scheduled by the Mexico CRSP to be taken every month. However, because of delays in identifying and enrolling pregnant women, the number of women pre-pregnancy and during the first trimester is small. To reduce the number of correlations, only the triceps and subscapular skinfolds results are presented.

Brazelton Scores

Table 13.10 shows the Pearson correlations between the Brazelton scores and maternal anthropometry. There is little consistent relationship between maternal size and Brazelton scores. The one exception is *autonomic stability*, heavier and fatter mothers during the second and third trimesters tending to have babies showing fewer signs of physical stress.

Mother-Infant Interaction

Spearman correlations show little relationship between maternal anthropometry and mother-infant interaction at 3 months. However, less yawning was associated with heavier mothers during the

Table 13.7: Spearman correlations of infant size with Bayley Motor and Mental scores.

	N	Motor Highest	Motor % Passed	Mental Highest	Mental % Passed
At Birth					
Birth Weight	73	0.34‡	0.31†	0.33‡	0.26*
Birth Length	64	0.10	0.20	0.18	0.28*
Weight/length^3	64	0.26*	0.14	0.09	-0.02
Head Circumference	45	0.19	0.21	0.09	0.14
At 3 mo					
Weight	74	0.28*	0.29*	0.26*	0.31†
Length	74	0.30*	0.27*	0.25*	0.36‡
Weight/length^3	74	-0.05	0.01	0.04	-0.02
Head Circumference	74	0.21	0.23*	0.13	0.27*
At 6 mo					
Weight	60	0.21	0.15	0.11	0.24
Length	61	0.27*	0.24	0.13	0.28
Weight/length^3	60	0.03	-0.01	0.05	0.08
Head Circumference	61	0.20	0.15	-0.05	0.10
Growth rates					
Weight (0-3 mo)	64	0.06	0.13	0.10	0.24
Length (0-3 mo)	58	0.13	0.08	0.06	0.07
Weight (3-6 mo)	52	-0.07	0.03	-0.12	0.12
Length (3-6 mo)	53	-0.12	-0.00	-0.06	0.05
Weight (0-6 mo)	48	0.08	0.05	0.07	0.25
Length (0-6 mo)	43	0.07	0.07	0.02	0.11

* $p < 0.10$ † $p < 0.05$ ‡ $p < 0.01$

second (r=-0.21, p<0.10, N=80) and third trimesters (r=-0.20, p<0.10, N=82), and post-partum (r=-0.19, p<0.10, N=82). Less squirming was also associated with larger biceps skinfolds during the third trimester (r=-0.23, p<0.05, N=78) and post-partum (r=-0.24, p<0.05, N=69).

At 6 months, infants who smiled more tended to have mothers who were heavier and fatter in the first (*weight*: r=0.25, p<0.10, N=55; *triceps*: r=0.34, p<.0.05, N=55) and second

Table 13.8: Correlations of infant size with Bayley Infant Behavior Record Cognitive Factor scores (6 mo).

	N	Object Orien	Goal Direct	Attention Span	React	Gross Mo Coor	Fine Mo Coor.	Total Cog. Fact
At Birth								
Birth Weight	73	0.27*	0.13	0.19	0.18	0.20	0.31†	0.26*
Birth Length	64	0.19	0.05	0.05	0.01	0.03	-0.09	0.07
Weight/lgth^3	64	0.05	0.07	0.13	0.18	0.23	0.37‡	0.19
Head Circ	45	0.34*	0.24	0.20	0.09	0.17	0.13	0.28
At 3 mo								
Weight	74	0.15	0.03	0.08	0.06	0.22	0.20	0.11
Length	74	0.14	0.01	0.10	0.08	0.17	0.24*	0.11
Weight/lgth^3	74	0.01	-0.03	-0.04	-0.04	0.01	-0.02	-0.04
Head Circ	74	0.15	0.06	0.13	0.15	0.17	0.08	0.15
At 6 mo								
Weight	60	0.07	0.05	0.08	-0.06	0.09	0.17	0.09
Length	61	0.16	0.08	0.17	0.11	0.22	0.26*	0.20
Weight/lgth^3	60	-0.08	-0.05	-0.11	-0.20	-0.04	0.02	-0.08
Head Circ	61	-0.04	-0.04	0.01	0.00	0.18	0.07	0.04
Growth rates								
Weight (0-3 mo)	64	0.04	-0.12	-0.03	-0.06	0.11	0.04	-0.06
Length (0-3 mo)	58	-0.07	0.04	0.11	0.16	0.15	0.34†	0.10
Weight (3-6 mo)	52	0.08	0.08	0.19	-0.01	-0.05	0.02	0.11
Length (3-6 mo)	53	0.16	0.20	0.24	0.23	-0.07	-0.03	0.19
Weight (0-6 mo)	48	0.13	0.03	0.14	-0.03	0.01	0.12	0.10
Length (0-6 mo)	43	0.07	0.07	0.02	0.11	0.19	0.35*	0.21

* $p < 0.10$ † $p < 0.05$ ‡ $p < 0.01$

Table 13.9: Correlations of infant size with Bayley Infant Behavior Record Extraversion scores (6 mo).

	N	Social Orientation	Coopera-tivenes	General Emot Tone	Total Extraversion
At Birth					
Birth weight	73	0.16	0.19	0.24*	0.23
Birth length	64	0.06	0.10	0.16	0.11
Weight/lgth³	64	0.13	0.11	0.11	0.13
Head Circ	45	0.13	0.11	0.18	0.16
At 3 mo					
Weight	74	0.23*	0.10	0.13	0.14
Length	74	0.25*	0.10	0.16	0.16
Weight/lgth³	74	0.02	0.02	0.01	0.02
Head Circ	74	0.17	0.10	0.10	0.13
At 6 mo					
Weight	60	0.45§	0.15	0.22	0.27*
Length	61	0.48 ‖	0.15	0.32*	0.33†
Weight/lgth³	60	0.11	0.02	-0.08	-0.01
Head Circ	61	0.27*	-0.05	0.08	0.09
Growth rates					
Weight (0-3 mo)	64	0.18	0.06	0.02	0.06
Length (0-3 mo)	58	0.14	0.07	0.10	0.10
Weight (3-6 mo)	52	0.21	0.15	0.13	[illegible]
Length (3-6 mo)	53	0.31*	0.26	0.26	0.30*
Weight (0-6 mo)	48	0.46§	0.23	0.24	0.31*
Length (0-6 mo)	43	0.44‡	0.14	0.22	0.27

* $p < 0.10$ † $p < 0.05$ ‡ $p < 0.01$ § $p<0.005$ ‖ $p<0.001$

Table 13.10: Pearson correlations among NBAS cluster scores and selected maternal anthropometry.

	Pre-Preg (N=16)			1st Tri (N=26)			2nd Tri (N=42)			3rd Tri (N=45)		
	Wt	Tri	Subsc	Wt	Tri	Subsc	Wt	Tri	Subsc	Wt	Tri	Subsc
Habituation	-0.11	0.06	0.19	-0.02	0.20	0.26	0.16	0.30•	0.19	0.02	0.08	0.11
Orientation	0.40	0.11	0.30	-0.01	-0.35	0.16	-0.02	-0.01	0.14	-0.01	-0.12	0.02
Motor	0.26	-0.03	0.16	-0.00	-0.38•	0.06	0.07	-0.16	0.21	-0.00	-0.17	0.06
Range of State	0.08	-0.27	0.10	-0.25	-0.13	-0.01	0.02	-0.00	-0.06	0.02	0.13	0.10
Regulation of State	-0.27	-0.25	-0.12	0.09	-0.32	-0.04	0.11	0.11	0.23	0.14	0.04	0.29•
Autonomic Stability	0.16	-0.07	0.07	0.51‡	0.09	0.51†	0.31†	-0.11	0.26	0.37†	0.20	0.26•
Reflexes	0.23	0.04	0.09	0.26	0.20	0.19	0.14	-0.07	0.07	0.32†	0.16	0.08

• $p < 0.10$ † $p < 0.05$ ‡ $p < 0.01$

Table 13.11: Spearman correlations of maternal weight gain with Bayley Motor and Mental scores (6 mo).

		Motor		Mental	
	N	Highest	% Passed	Highest	% Passed
Wt Gain - Total	31	0.14	-0.10	0.12	0.08
Wt Gain - 2nd Trimester	31	-0.09	-0.25	-0.24	-0.32•
Wt Gain - 3rd Trimester	73	-0.29†	-0.26†	-0.30‡	-0.11

• $p<0.10$ † $p<0.05$ ‡ $p<0.01$ § $p<0.005$ ‖ $p<0.001$

Table 13.12: Correlations of maternal anthropometry with Bayley Infant Behavior Record Extraversion scores (6 mo).

	N	Social Orientation	Coopera-tivenes	General Emot Tone	Total Extraversion
Pre-pregnancy					
Weight	32	0.20	0.11	-0.09	0.04
Triceps	32	0.19	0.18	0.06	0.14
Subscapular	32	0.23	0.19	0.05	0.14
First trimester					
Weight	54	0.30†	0.30†	0.20	0.27*
Triceps	46	0.10	0.12	-0.13	-0.01
Subscapular	46	0.26*	0.20	0.03	0.18
Second trimester					
Weight	80	0.25†	0.27†	0.23	0.29‡
Triceps	74	0.07	0.17	0.12	0.17
Subscapular	74	0.26†	0.18	0.17	0.24†
Third trimester					
Weight	82	0.19*	0.22†	0.18*	0.22†
Triceps	78	0.16	0.10	0.12	0.13
Subscapular	78	0.20*	0.14	0.19*	0.21*
Postpartum					
Weight	82	0.21*	0.22†	0.17	0.22†
Triceps	69	0.08	-0.00	-0.01	0.03
Subscapular	69	0.18	0.17	0.27†	0.26†

trimesters (*weight*: $r=0.25$, $p<0.05$, $N=74$; *triceps*: $r=0.24$, $p<0.05$, $N=74$). Larger triceps during the first trimester were also associated with less fussing ($r=-0.33$, $p<0.05$, $N=47$) and squirming ($r=-0.29$, $p<.05$, $N=57$). However, larger triceps in the second trimester were associated with more yawning ($r=0.21$, $p<.10$) and brow knitting ($r=0.27$, $p<.05$, $N=74$). Only two of the infant interaction *ratings* had sizeable Kendall's correlations with maternal anthropometry. Infants who were rated as smiling frequently tended to have mothers who were heavier (*tau-b*=0.21, $p<0.10$, $N=53$) and with larger subscapular skinfolds (*tau-b*=0.30, $p<0.05$, $N=45$) in the first trimester. Infants who were rated as being more physically relaxed tended to have mothers who weighed less in the third trimester (*tau-b*=-0.14, $p<0.10$, $N=81$) and post-partum (*tau-b*=-0.18, $p<0.05$, $N=81$). These women also tended to have larger skinfolds (*pre-pregnancy triceps*: *tau-b*=-0.28, $p<0.10$, $N=31$; *2nd trimester triceps*: *tau-b* =-0.16, $p<0.10$, $N=73$; and *2nd trimester subscapular*: *tau-b*=-0.16, $p<0.10$, $N=73$).

Bayley Scores

Bayley Motor and mental scores showed few sizeable correlations with maternal anthropometry. One exception was a tendency for the infants of fatter mothers to do better on the mental exam. Infants who passed a higher proportion of mental items tended to have mothers who were heavier during pre-pregnancy ($r=0.33$, $p<0.10$, $N=32$) and the first trimester ($r=0.26$, $p<0.10$, $N=54$). These mothers also tended to gain less weight in the second trimester ($r=-0.32$, $p<0.10$, $N=31$)(see Chapter Eleven). Also, infants who passed higher Bayley mental items tended to have mothers with larger triceps ($r=0.46$, $p<0.01$, $N=32$) and subscapular ($r=0.39$, $p<0.05$, $N=32$) skinfolds pre-pregnancy. Smaller gains in weight during the 3rd trimester were associated with the highest Bayley mental item passed ($r=-0.29$, $p<0.05$, $N=73$), a higher proportion of Bayley motor items passed ($r=-0.26$, $p<0.05$, $N=73$), and the highest Bayley mental item passed ($r=-0.30$, $p<0.01$, $N=73$). Also, better performance on Bayley Mental and Motor scales was associated with less weight gain during the second and third trimesters (Table 13.10).

For the Infant Behavior Record, there was little relationship between the cognitive factor items. The exceptions are an association between poor fine motor coordination and smaller maternal triceps skinfolds in the first trimester ($r=-0.27$, $p<0.10$, $N=46$), and poor gross motor coordination and smaller triceps skinfold in the second trimester ($r=-0.27$, $p<0.05$, $N=74$). In contrast, the extraversion items had several sizeable correlations with maternal weight and subscapular skinfolds, heavier and fatter mothers tending to have children who were more friendly, more cooperative, and generally happier (Table 13.12).

Summary: Effects of Maternal Anthropometry

The correlation analyses suggest a role of maternal anthropometry, in particular maternal fatness, in infant cognitive performance and behavior. As seen with infant anthropometry, there is little apparent relationship between maternal anthropometry and the Brazelton exam scores with the exception of *autonomic stability* (startle response and tremors). In this case, fatter mothers in the second and third trimesters had infants who showed better *autonomic stability*. The infant interaction variables showed less yawning at 3 months by infants of heavier mothers during pregnancy. Less squirming at 3 months was associated with maternal fatness both during pregnancy and post-partum. At 6 months, infants who smiled more tended to have mothers who were heavier and fatter in early pregnancy. Infants who were rated as less relaxed tended to be of heavier mothers. As with infant size, this may be due to a tendency of the infants of thinner women to be more passive. Better Bayley mental performance was associated with heavier and fatter mothers pre-pregnancy, and less weight gain during the second trimester (fatter mothers pre-pregnancy tended to gain less weight - see Chapter Eleven). Poorer motor coordination was also associated with thinner women in the first and second trimesters. The children of heavier and fatter mothers tended to show greater extraversion than did children of thinner and lighter women.

Maternal Diet and Infant Psychology

The following section focuses on the relationship between maternal dietary intake during pregnancy and lactation. As measures of maternal intake during pregnancy and lactation are often highly correlated, the exact timing of any dietary effects must be considered unknowable given the local pattern of diet (Chapters Six and Seven).

Brazelton Scores

Table 13.13 shows the Spearman correlations between maternal diet as measured during pregnancy and the NBAS scores. Several maternal dietary variables have large correlations with infants *habituation*, better scores being associated with higher intakes of animal kcal, % animal kcal, ascorbic acid, niacin, riboflavin, total iron, heme iron, and *pulque* (which is high in iron and ascorbic acid). Better bioavailability (available iron, phytate/zinc and fiber/iron ratios) were also associated with better habituation. An examination of the items comprising the scale show habituation to light, the rattle, and the bell to be more strongly correlated with maternal intake than habituation to the pinprick.

Mother-Infant Interaction

Maternal diet during pregnancy showed little relationship to infant interaction at 3 months. Less smiling was associated with mothers who consumed more *pulque* ($r=-0.30$, $p<0.05$, $N=82$), better fiber/iron ratio ($r=0.27$, $p<0.10$, $N=82$), and less niacin ($r=-0.20$, $p<0.10$, $N=82$). Maternal diet during the first three months following birth also showed little relationship to infant interaction at 3 months.

At 6 months, few maternal nutrient variables during pregnancy had sizeable correlations with infant interaction. The exceptions were positive correlations between the frequency of the infant's looking at the mother and her mean protein ($r=0.19$, $p<0.10$, $N=82$) and fat intake ($r=0.30$, $p<0.01$, $N=82$). Also, fussiness was associated with more calcium ($r=0.21$, $p<0.10$, $N=82$) and riboflavin ($r=0.18$, $p<0.10$, $N=82$). A higher phytate/zinc ratio was associated with less looking at the mother ($r=-0.21$, $p<0.10$, $N=82$) and less smiling ($r=-0.22$, $p<0.05$, $N=82$). A higher fiber/iron ratio was associated with less cooing ($r=-0.21$, $p<0.10$, $N=82$). These nutrient variables probably reflect a higher consumption of *tortillas* (Chapter Six). As seen in Chapter Six for preschooler anthropometry, the pregnancy dietary quality variables tend to be better predictors of infant behaviors (Table 13.13). Higher dietary quality tended to be associated with more moving of limbs, more cooing, more smiling, more brow knitting, and more laughing.

The mother's diet during lactation also showed few sizeable relationships with infant interaction at 6 months. However, infants who laughed more were associated with mothers with better phytate/zinc ratios ($r=-0.26$, $p<0.05$, $N=85$) and who consumed more retinol ($r=0.18$,

Table 13.13: Spearman correlations of maternal dietary intake variables with Brazelton examination scores (N= 45).

	Habituation	Orientation	Motor	Range of State	Regulation of State	Autonomic Stability	Reflexes
N of Recalls	0.26*	0.11	0.09	-0.24	0.54 ‖	-0.07	-0.18
Total kcal	0.23	0.05	-0.19	-0.13	-0.02	0.16	-0.07
Total Protein	0.24	-0.00	-0.29*	-0.09	-0.12	0.14	0.03
Animal kcal	0.37†	-0.03	-0.21	0.03	0.01	0.17	-0.02
% Animal kcal	0.26*	-0.08	-0.18	0.04	-0.03	0.16	-0.05
% *Tortilla* kcal	-0.16	0.09	0.14	0.05	-0.02	-0.06	0.05
Kcal from *Pulque*	0.45§	-0.09	-0.18	-0.12	0.15	-0.20	-0.16
Ascorbic Acid	0.53 ‖	-0.08	-0.19	-0.05	0.18	-0.08	-0.03
Retinol	0.19	0.03	-0.12	-0.05	0.17	0.11	-0.06
Thiamin	0.25*	-0.09	-0.31†	-0.07	-0.10	-0.04	0.04
Niacin	0.30†	-0.02	-0.26*	-0.02	-0.02	0.07	-0.02
Riboflavin	0.32†	-0.02	-0.26*	-0.03	-0.02	0.05	0.08
Vitamin B_6	0.30*	-0.13	-0.27*	-0.14	0.07	-0.10	0.01
Folate	0.14	0.03	-0.29*	-0.20	-0.02	-0.11	-0.03
Vitamin B_{12}	0.18	-0.04	0.03	0.10	-0.07	0.02	0.24
Calcium	0.28*	0.10	-0.19	0.02	-0.04	0.02	-0.03
Zinc	0.23	-0.05	-0.27*	-0.08	-0.08	0.11	-0.01
Total Iron	0.34†	-0.01	-0.25	-0.05	-0.07	0.15	0.02
Available Iron	0.51 ‖	-0.07	-0.28*	-0.00	0.00	0.09	-0.01
Heme Iron	0.43§	-0.19	-0.11	-0.06	0.12	0.09	-0.03
Fiber/iron	-0.48 ‖	-0.02	0.01	-0.15	0.05	-0.02	-0.03
Phytate/zinc	-0.40‡	0.30†	0.28*	-0.00	-0.08	-0.00	-0.10

* $p < 0.10$ † $p < 0.05$ ‡ $p < 0.01$ § $p < 0.005$ ‖ $p < 0.001$

Table 13.14: Spearman correlations of maternal dietary quality during pregnancy with infant interaction variables (6 mo).

	Moves Limbs	Looks at Mother	Coos	Smiles	Squirms	Fusses	Knits Brow	Yawns	Laughs
% Animal	0.21†	0.15	0.23†	0.25†	0.03	-0.14	0.30‡	0.08	0.13
% Meat	0.29†	0.06	0.29‡	0.06	0.04	-0.09	0.28	-0.11	0.03
% Eggs	0.10	0.15	0.13	0.11	0.05	-0.06	-0.07	0.07	0.24†
% Dairy	0.10	0.19	0.04	0.28†	0.09	-0.10	0.34§	0.21*	0.04
% Plant	-0.22†	-0.16	-0.23†	-0.25†	-0.03	0.14	-0.30‡	-0.08	-0.13
% *Tortillas*	-0.16	-0.21*	-0.09	-0.27†	0.01	0.14	-0.09	-0.11	-0.27†
% Legumes	0.10	-0.09	-0.14	-0.08	-0.04	0.17	-0.03	0.01	0.01
% Vegetables	-0.17	0.12	-0.20*	-0.04	-0.08	0.04	-0.11	-0.06	0.04
% *Pulque*	-0.10	0.02	-0.02	0.03	0.13	0.03	-0.15	0.13	0.04
% Fruit	-0.08	0.06	0.12	0.06	-0.08	0.14	0.05	-0.02	0.07
% Other Plant	0.17	-0.03	-0.11	0.09	-0.08	0.05	-0.10	-0.08	0.14

Table 13.15: Spearman correlations of maternal dietary quality post-partum and Bayley Motor and Mental scores (6 mo).

	Motor		Mental	
	Highest	% Passed	Highest	% Passed
% Animal	0.08	0.07	0.13	0.15
% Meat	0.08	-0.05	0.18	0.09
% Eggs	0.16	0.17	0.16	0.14
% Dairy	-0.03	0.02	-0.01	0.13
% Plant	-0.08	-0.07	-0.13	-0.15
% *Tortillas*	0.05	-0.07	-0.15	-0.14
% Legumes	-0.09	-0.04	-0.22*	-0.20
% Vegetables	-0.00	-0.04	0.06	0.01
% *Pulque*	0.08	0.00	0.25†	0.07
% Fruit	0.08	0.08	0.11	0.31‡
% Other Plant	-0.02	0.18	0.08	0.23†

$p<0.10$, N=85). Children who yawned more had mothers who consumed less available iron (-0.22, $p<0.05$, N=85), niacin (r=-0.22, $p<0.05$), and phytate (r=-0.19, $p<0.10$), more dairy (r=0.20, $p<0.10$), fewer eggs (r=-0.21, $p<0.10$), more vegetables (r=0.22, $p<0.05$), and more fruit (r=0.21, $p<0.05$).

In general, maternal diet during pregnancy and post-partum showed little relationship to infant interaction ratings. However, infants who smiled more often tended to have mothers who during pregnancy consumed more heme iron (r=0.19, $p<0.05$, N=81), had better phytate/zinc ratios (r=-0.21, $p<0.05$, N=81), and consumed a higher proportion of energy from animal products (r=0.23, $p<0.01$, N=83) and meat (r=0.17, $p<0.10$, N=83), and less from plant sources (r=-0.23, $p<0.01$, N=81) and *tortillas* (r=-0.25, $p<0.01$, N=81). These infants also had mothers who during lactation consumed more heme iron (r=0.23, $p<0.01$, N=85).

Bayley Scores

Bayley motor scores showed little relationship to maternal intake during pregnancy. In contrast, better Bayley mental scores were associated with less fiber (% passed: r=-0.18, $p<0.10$, N=82), better phytate/zinc ratio (highest: r=-0.23, $p<0.05$; % passed: r=-0.23, $p<0.05$), a better fiber/iron ratio (highest: r=-0.29, $p<0.01$; % passed: r=-0.24, $p<0.05$), more animal kcal(r=0.18, $p<0.10$), fewer legumes (highest: r=-0.22, $p<0.10$; % passed: r=-0.20, $p<0.10$), and more fruit (% passed: r=0.20, $p<0.10$).

Bayley motor and mental scores had more sizeable correlations with maternal intake post-partum. Higher motor scores were associated with less energy consumption (% passed: r=-0.21, $p<0.10$, N=86), less energy from *tortillas* (r=-0.21, $p<0.05$), and more fruit (r=0.23, $p<0.05$). Higher motor scores were also associated with lower consumption of a series of nutrients associated with more energy and *tortilla* intake (including total iron, available iron, heme iron, zinc, fiber, protein, calcium, thiamin, riboflavin, and niacin). Better Bayley mental scores were associated with less maternal consumption of fiber (highest: r=-0.23, $p<0.05$; % passed: r=-0.21, $p<0.10$), phytate (highest: r=-0.18, $p<0.10$: % passed: r=-0.23, $p<0.05$), and lower fiber/iron ratios (highest: r=-0.36, $p<0.001$: % passed: r=-0.23, $p<0.05$). Mothers of infants with better Bayley mental scores consumed, more fruit (% passed: r=0.31, $p<0.005$), and fewer legumes (highest: r=-0.36, $p<0.001$: % passed: r=-0.28, $p<0.01$).

The Infant Behavior Record items also had sizeable correlations with several maternal dietary intake measures during pregnancy. One variable consistently associated with IBR measures was the phytate/zinc ratio, lower maternal phytate/zinc ratios during pregnancy being associated with infant's happier appearance (*object orientation*: r=-0.24, $p<0.05$, N=82), better *attention span* (r=-0.19, $p<0.10$), more *reactivity* (r=-0.21, $p<0.10$), greater friendliness (*social orientation*: r=-0.21, $p<0.10$), more *cooperativeness* (r=-0.23, $p<0.05$), and better *general emotional tone* (r=-0.22, $p<0.05$). A higher proportion of energy from fruit was also associated with the infant's happier appearance (*object orientation*: r=0.32, $p<0.005$, N=82), more *goal directedness* (r=0.23, $p<0.05$), better *attention span* (r=0.28, $p<0.05$), more *reactivity*

($r=0.34$, $p<0.005$), greater friendliness (*social orientation*: $r=0.25$, $p<0.05$), more *cooperativeness* ($r=0.29$, $p<0.01$), and better *general emotional tone* ($r=0.24$, $p<0.05$). More meat energy was associated with greater friendliness (*object orientation*: $r=0.26$, $p<0.05$) and better *general emotional tone* ($r=0.21$, $p<0.10$).

The pattern for maternal diet during lactation was similar to that seen for the pregnancy dietary measures. The fiber/iron ratio was again a consistent predictor of IBR measures. Better fiber/iron ratios were associated with infant's happier appearance (*object orientation*: $r=-0.31$, $p<0.005$, $N=86$), more *goal directedness* ($r=-0.20$, $p<0.10$), better *attention span* ($r=-0.36$, $p<0.001$), more *reactivity* ($r=-0.32$, $p<0.005$), better *fine motor control* ($r=-0.24$, $p<0.05$), and better *general emotional tone* ($r=-0.25$, $p<0.05$). As during pregnancy, a higher proportion of energy from fruit was associated with infant's happier appearance (*object orientation*: $r=0.29$, $p<0.01$), more *goal directedness* ($r=0.28$, $p<0.01$), better *attention span* ($r=0.26$, $p<0.05$), and more *reactivity* ($r=0.24$, $p<0.05$).

Summary: The Effects of Maternal Diet

Several maternal dietary variables during pregnancy have large correlations with her infant's *habituation* (the ability of the infant to respond to stimuli during sleep and then inhibit that response) at birth. Better *habituation* scores were associated with higher intakes of animal kcal, % animal kcal, ascorbic acid, niacin, riboflavin, total iron, heme iron, and *pulque*. Higher intakes of available iron, and lower phytate/zinc and fiber/iron ratios were also associated with better *habituation*. Infant behavior at 3 months showed little relationship to maternal intake during either pregnancy or lactation. At 6 months, better dietary quality was associated with more moving of limbs, more cooing, more smiling, more brow knitting, and more laughing. Bayley motor scores showed little relationship to maternal diet during pregnancy. However, maternal intake during lactation had several sizeable correlations. Better motor scores tended to be associated with fewer *tortillas* and more fruit. Bayley mental scores were associated with higher maternal intakes of animal kcal, better bioavailability, and more fruit during pregnancy. Similarly, better Bayley mental scores were associated with better bioavailability, lower consumption of fiber and phytate, and higher intake of fruit during lactation.

Maternal Biochemistry and Infant Psychology

Because of the Nutrition CRSP's focus on energy, relatively few biochemical measures were made (see Chapter Eight), and women often did not have blood measures during pregnancy and lactation. As a result, the sample N's are rather small.

Brazelton Examination

Only 28 mothers of infants with NBAS have any pregnancy blood measures (hematocrit, hemoglobin, and Mean Corpuscular Volume), and still fewer have measures of ferritin ($N=18$), prealbumin (N=20), and transferrin (N=21). Only 12 mothers have measures of serum B_{12}. As a result, few statistical conclusions can be drawn. For the 18 mothers with plasma ferritin measures, higher plasma ferritin was associated with somewhat better *habituation* (r=0.20, ns), *orientation* (r=0.24, ns), *motor* (r=0.46, p<0.10), and *autonomic stability* scores (r=0.27, ns). Higher plasma B_{12} was associated with better *orientation* (r=0.47, ns, N=12), better *motor performance* (r=0.33, ns, N=12), and worse *regulation of state* (r=-0.70, p<0.05, N=12).

Mother-Infant Interaction

As with the Brazelton examination, an understanding of the relationship of maternal biochemistry to infant interaction is hindered by low N's. Lower plasma B_{12} during pregnancy had non-significant relationships at 3 months with less looking at the mother (r=0.27, N=27), less cooing (r=24, N=27), and less laughing (r=24, N=27). At 6 months, low plasma B_{12} during pregnancy was also associated with less looking at the mother (r=0.46, p<0.05, N=27). Lower plasma B_{12} during lactation was again associated with less looking at the mother (r=0.27, ns, N=18), more fussiness (r=-0.50, p<0.05, N=18), more moving of arms (r=-0.26, ns, N=18), and more squirming (r=-0.36, ns, N=18) at 3 months. At 6 months, lower serum B_{12} was associated with more observed fussing (r=-0.32, ns, N=18). Also at 6 months, higher pregnancy B_{12} was associated with ratings of less averting of the face (r=0.45, p<0.01, N=26), more looking at the mother (r=0.41, p<0.05, N=26), and less agitation (r=0.30, p<0.10, N=26). Higher plasma B_{12} levels during lactation were also associated with more relaxed infants (r=0.34, p<0.10, N=17), less averting of the face (r=0.32, ns, N=17), and more looking at mother (r=0.32, ns, N=17). These suggestive results are offset by negative associations between milk B_{12} levels and observed laughing at 3 months (r=-0.30, p<0.05, N=42), and observed smiling at 6 months (r=-0.27, p<0.10, N=44).

Pregnancy and lactation iron status measures show little relationship with infant interaction at either 3 or 6 months, or infant interaction ratings at 6 months.

Bayley Examination

The Bayley Motor and Mental measures suggest no relationship between maternal B_{12} status and motor and mental development, the milk and plasma measures having low correlations with the mental and motor scores. However, higher maternal plasma B_{12} levels during pregnancy were somewhat associated with better gross (r=0.27, ns, N=27) and fine *motor coordination* (r=0.29, ns, N=27), and worse *general emotional tone* (r=-0.29, ns, N=27). And, higher maternal plasma B_{12} was associated with *worse* scores on most IBR scales. Milk B_{12} (N=44) showed little relationship to any of the IBR measures.

Iron status measures in pregnancy show some relationship to the motor, mental, or IBR measures. There is a moderate correlation between serum transferrin and the highest motor item passed (r=0.40, p<0.10, N=55). In pregnancy, hemoglobin levels show little relationship to the Bayley items. However, higher serum ferritin was associated with higher motor (highest: $r=0.41$, $p<0.05$, $N=25$; % passed: $r=0.31$, ns) and mental scores (% passed: $r=0.34$, $p<0.10$, $N=25$). Higher serum ferritin post-partum was also associated with more friendliness (*social orientation*: $r=0.38$, $p<0.10$, $N=25$).

Higher post-partum serum pre-albumin was associated with higher motor (highest: $r=0.33$, $p<0.10$, $N=33$) and mental scores (% passed: $r=0.34$, $p<0.10$, $N=33$), and higher scores on object orientation ($r=0.30$, $p<0.10$), goal directedness ($r=0.32$, $p<0.10$), attention span ($r=0.56$, $p<0.001$), reactivity ($r=0.38$, $p<0.05$), social orientation ($r=0.48$, $p<0.005$), cooperativeness ($r=0.50$, $p<0.005$), and general emotional tone ($r=0.47$, $p<0.01$).

Infant Diet and Infant Psychology

Mother-Infant Interaction at 3 Months

Only 27 of 86 infants (31%) with interaction data at 3 months were recorded as consuming supplementary foods. Energy intakes from these non-breastmilk foods ranged up to 350 kcal, the median intake being approximately 22 kcal per day. Most of this energy was either from refined sugar or milk. Higher energy intake was associated with less laughing ($r=-0.21$, $p<0.10$), and less yawning ($r=-0.27$, $p<0.05$). More yawning was also associated with less sugar ($r=-0.24$, $p<0.05$).

Mother-Infant Interaction at 6 Months

Infant interaction showed no relationship to breastmilk supplementation during the first 3 months. The frequency of infant diet supplementation by 6 months was 51 of 85 (40.5%). In general, supplementation during 3 to 6 months also showed little relationship to infant interaction. One exception was squirming, more squirming being associated with more total kcal ($r=0.30$, $p<0.01$), more maize ($r=0.24$, $p<0.05$), more flour (maize, rice, and wheat used in the preparation of the drink *atole*)($r=0.36$, $p<0.001$), more sugar ($r=0.26$, $p<0.05$), more *tortillas* ($r=0.20$, $p<0.10$), and more beans ($r=0.22$, $p<0.05$).

The interaction ratings showed virtually no relationship with infant feeding. One exception was an association between a relaxed body and fewer total kcal ($r=-0.21$, $p<0.05$) and less milk ($r=-0.22$, $p<0.05$).

Bayley Exam

Infant feeding during 0-3 months showed several sizeable correlations with Bayley items at 6 months. Higher energy intake was associated with better motor scores (% passed: $r=0.22$, $p<0.05$, $N=86$), more *goal directedness* ($r=0.30$, $p<0.01$), more *reactivity* ($r=0.20$,

$p<0.10$), and better *general emotional tone* ($r=0.22$, $p<0.05$). More sugar was also associated with higher motor scores (highest: $r=0.23$, $p<0.05$; % passed: $r=0.30$, $p<0.01$), more *goal directedness* ($r=0.35$, $p<0.001$), better *attention span* ($r=0.22$, $p<0.05$), more *reactivity* ($r=0.25$, $p<0.05$), better gross motor ($r=0.23$, $p<0.05$) and fine *motor coordination* ($r=0.27$, $p<0.05$), greater *social orientation* ($r=0.22$, $p<0.05$), and better *general emotional tone* ($r=0.25$, $p<0.05$). However, consumption of milk during 0 to 3 months showed little association with any of the Bayley measures.

Infant feeding during 3 to 6 months showed associations between a higher intake of eggs, milk and fruit and more *goal directedness* (eggs: $r=0.24$, $p<0.05$; milk: $r=0.27$, $p<0.05$; fruit: $r=0.19$, $p<0.10$) and better *attention span* (eggs: $r=0.23$, $p<0.05$; milk: $r=0.21$, $p<0.05$; fruit: $r=0.21$, $p<0.10$). Higher consumption of masa (in *atole*) was associated with better mental (highest: $r=0.31$, $p<0.005$) and motor scores (highest: $r=0.29$, $p<0.01$). Higher consumption of 'other foods' (e.g., pasta, potatoes, bread, etc.) was associated with higher motor scores (highest: $r=0.20$, $p<0.10$), mental scores (highest: $r=0.30$, $p<0.01$), better *attention span* ($r=0.23$, $p<0.05$), more *social orientation* ($r=0.22$, $p<0.05$, and better *general emotional tone* ($r=0.24$, $p<0.05$).

Sociocultural Factors and Infant Psychology

To investigate the effects of social factors on infant psychology and behavior, correlations were calculated between the infant measures and 8 household variables (household material wealth, household energy needs, ownership of chickens, ownership of cows, appearance of the yard, and appearance of the inside of the house) and 8 maternal and 8 paternal variables (age, level of education, reading ability, aspirations for children's schooling, aspirations for children's occupations, number of trips from the valley per year, knowledge of development programs, and knowledge of non-valley facts).

Mother-Infant Interaction at 3 Months

Neither household wealth nor household energy needs (household size) bore much relationship to infant interaction at 3 months. More looking at the mother was associated with the better appearance of the yard ($r=0.29$, $p<0.01$, $N=86$) and house ($r=0.23$, $p<0.05$, $N=86$), and more maternal trips from the valley ($r=0.21$, $p<0.10$, $N=83$). In general, infant interaction showed little relationship to the social variables.

Mother-Infant Interaction at 6 Months

Both infant interaction observation and ratings variables showed little relationship to any of the household and parental social variables.

Bayley Exam

In general, there was little relationship between the social variables and Bayley scores. Neither household material wealth nor household energy needs (Chapter Seven) had sizeable correlations with any of the Bayley items. More trips by the mother to outside of the valley was associated with poorer motor scores (highest passed: $r=-0.20$, $p<0.10$, $N=83$), greater friendliness (object orientation: $r=0.27$, $p<0.05$, $N=83$), more goal orientation ($r=0.19$, $p<0.10$, $N=83$), and greater social orientation ($r=0.21$, $p<0.10$, $N=83$).

Discussion

The results presented in this chapter are provocative and suggestive. However, the exact nature of any relationships are made less clear by varying sample sizes, small Ns, and the large number of different psychological, anthropometric, and dietary variables. Nevertheless, certain regularities can be seen.

In Chapter Five, infancy in the Solís Valley was shown to be a period steady growth faltering. It has been argued that the small size of Third World children is not necessarily indicative of any deficiency that is important in terms of human quality of life. In this chapter, small infant size is associated with both infant behavior and motor and mental performance. Lower birth weight babies showed more startle response, tremors, and changes in skin color when examined shortly after birth. Perhaps the best predictor of motor and mental performance at 6 months of age is birth weight. Larger infants in general appear to smile more, look at the mother more, are more vocal, and are more social and less withdrawn. Given these results, it seems fair to say that small is not healthy. In fact, the negative effect of birth weight on motor and mental performance at 6 months suggests that small may be a prelude to lasting psychological deficit.

The causes of physical and psychological deficits are still unknown. However, many of the results presented in this chapter are suggestive of causes. The analyses presented in this chapter show maternal weight and fatness to be a marker of biological processes that affect the infant's behavior and psychological growth. Fatter mothers in the second and third trimesters gave birth to infants who showed better *autonomic stability* (less startle response and tremors). At 6 months, infants who smiled more tended to have mothers who were heavier and fatter in early pregnancy. Better Bayley mental performance was associated with heavier and fatter mothers pre-pregnancy, and less weight gain during the second trimester, and poorer motor coordination was associated with thinner women in the first and second trimesters. In addition, the children of heavier and fatter mothers tended to show greater extraversion than did the children of thinner and lighter women.

These maternal effects would appear to be result of differences in the capacity of mothers to provide the infant with the nutrients it needs to grow optimally. Fairly consistent correlations suggest a role of dietary quality in infant psychological growth. Several maternal dietary variables have large correlations with infants *habituation* (the ability of the infant to respond to stimuli during sleep and then inhibit that response). Better *habituation* scores were associated with higher intakes of animal kcal, % animal kcal, ascorbic acid, niacin, riboflavin, total iron, heme iron, and *pulque*. Higher intakes of available iron, and lower phytate/zinc and fiber/iron ratios were also associated with better *habituation*. At 6 months, better dietary quality was associated with more moving of limbs, more cooing, more smiling, more brow knitting, and more laughing. Better motor scores tended to be associated with maternal consumption during lactation of fewer *tortillas* and more fruit. Similarly, the Bayley mental scores were associated with higher maternal intakes of animal kcal, better bioavailability, and more fruit during pregnancy. Better Bayley mental scores were also associated with better bioavailability, lower consumption of fiber and phytate, and higher intake of fruit during lactation.

The consistently negative effects of maternal intake of fiber and phytate (which reduce the bioavailability of minerals), and the positive associations with fruit consumption (which enhances the absorption of non-heme iron), suggest a possible role of iron and other mineral deficiencies in psychological and physical development of these children. Unfortunately, the number of biochemical measures on these mothers is fairly small. For 18 newborns, higher maternal levels of plasma ferritin were associated with somewhat better ability to adapt to intrusive environmental stimuli when sleeping, better ability to follow auditory and visual features of the environment, better motor performance, and less startle response and tremors during examination. At 6 months, higher serum transferrin and ferritin was associated with higher motor performance, and higher serum ferritin during pregnancy was associated with higher mental scores. During lactation, higher serum ferritin was also associated with more extraverted behavior.

High rates of vitamin B_{12} deficiency in the Solís Valley (Chapter Eight) raise a specter of permanent neurological damage to these children. However, our understanding of this possible condition is hindered by very small sample sizes. In general, the poor vitamin B_{12} status of the mother is associated with negative infant behaviors. However, the Bayley Motor and Mental scores suggest no relationship with maternal B_{12} status. Nevertheless, lower plasma B_{12} during pregnancy was associated with less looking at the mother, less cooing, less laughing, more fussiness, less agitation, and more squirming. Higher maternal plasma B_{12} levels during pregnancy were also associated with better gross and fine *motor coordination*, and worse *general emotional tone*. And, higher maternal plasma B_{12} was associated with *worse* scores on most IBR scales. Curiously, milk B_{12} (N=44) showed little relationship to any of the IBR measures.

The associations between maternal vitamin deficiencies and infant psychology variables suggest that supplemental feeding of these children could actually be beneficial if the correct foods were provided. In general, little relationship was seen between infant feeding during the first 3 months and infant behavior and motor and mental performance. However, infant feeding during 3 to 6 months showed associations between a higher intake of eggs, milk and fruit and more *goal directedness* and better *attention span*. Higher consumption of masa (*atole*) was associated with better mental and motor scores, as was higher consumption of 'other foods' (e.g., pasta, potatoes, bread, etc.). Consumption of 'other foods' was also associated with better *attention span*, a more *social orientation*, and better *general emotional tone*.

In general, there was little relationship between the social variables and infant behavior and motor and mental performance.

The results presented in this chapter suggest that maternal factors are an important determinant of variation in infant behavior and motor and mental development in the Solís Valley. Both motor and mental performance at 6 months appear to be influenced by conditions during pregnancy, especially birth weight. In addition, a series of qualities that are best described as the characteristics of a happy child appear to be most affected by variation in maternal size, diet, and biochemistry. Babies who laugh, smile, look at their mother, are friendly, and rarely fuss and squirm are more likely to be those of mothers who are heavier, fatter, and better fed. In Chapter Fifteen, a very similar picture is painted of Solís Valley preschoolers. Unfortunately, we do not currently know whether the children with deficits at 6 months will become the children with deficits at 30 months, or 6 years, or 60 years. This question deserves top priority for future research.

Policy Implications

- In the Solís Valley, smaller infants have poorer mental and motor performance at 6 months of age. In addition, larger infants appear to be happier, more social, and less withdrawn.

- Maternal body composition, maternal diet, and maternal biochemistry are all associated with variation in infant behavior and motor and mental performance. Infant birth weight appears to be a very important predictor of future motor and mental performance.

- Therefore, policies aimed at improving general maternal nutritional status and raising birth weights may prove fruitful. Also, a nutrient supplementation program for children with lower birth weights would merit special consideration.

- Iron deficiency and vitamin B_{12} deficiency of the mother may be important factors affecting infant behavior, even at birth, and motor and mental development.

- Supplemental feeding of infants does not appear to harm the psychological development of the infant. In fact, supplemental feeding with high quality foods may actually help the development of some children.

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Chapter Fourteen.
Dietary Quality and Preschooler Growth

Why Does Growth-Stunting Occur in Developing Countries?

Similar to most children in developing countries, Solís Valley infants experience growth-stunting relatively soon after birth. The most commonly-used explanations of growth faltering during infancy include inappropriate weaning practices and morbidity (especially diarrhea in malnourished children).

Preschoolers, who are already the victims of previous growth-faltering, have the potential for catch-up growth. However, their mean growth rate remained below, but parallel to, the NCHS reference values. As with infants, the generally accepted explanation for the persistence of growth-stunting in Third World children is high morbidity and poor diets within a social context of poverty. However, there remains a considerable lack of understanding about the role of specific nutrient deficiencies in this process. Nutrients that may play a role in the etiology of stunting include energy alone, protein and energy, essential amino acids, zinc and iron.

This chapter considers the causes of inter-individual variation in attained size and growth rate for the Solís preschoolers, examining the relationships of dietary intake (quality and quantity), maternal size, morbidity, and selected environmental variables to child growth and size.

Maternal size is included because of its strong positive relationship to infant growth (Chapter Eleven). Morbidity of preschoolers is usually higher than that of infants and many aspects of the local environment increase risk of disease, and subsequently growth: poor sanitation with 87% of households disposing of human waste in the fields surrounding the house; domestic animals in yards and in houses; 40% of houses having at least one earth floor; cramped accommodations; and contaminated water. Parasitic infections are endemic. For example, *Giardia lamblia* cysts were found in the feces of 18% of the preschoolers.

In addition to an unsanitary environment, the restricted nature of the Solís Valley diet might be inadequate to support optimal growth. As shown in Chapter Six, after weaning (which is relatively late) preschoolers obtain an average of 88% of their total energy from plant sources. Nevertheless, preschooler diets range from those that are simple, low in quality, and high in maize and beans, to those that are more complex, of higher quality and contain proportionally more animal products, fruits, milk, and a variety of other non-maize foods.

Age at weaning (defined as cessation of breastfeeding) and morbidity data were obtained as maternal reports. For statistical analyses, symptoms were later classified into the illness categories of diarrhea, upper respiratory, lower respiratory, fever, and runny nose.

Other data used in these analyses include socioeconomic status and household economics; parental anthropometry (weight every three months and length twice per year); maternal and paternal literacy (ability to read and/or write); and the number, age and sex of household members. These analyses have been published elsewhere [1].

Sample Selection and Variable Construction

Of the 110 preschoolers in the Mexico CRSP, some had incomplete data. For inclusion in these analyses a child was required to have a minimum of i) two weight and two length measures separated by a minimum of 90 days, ii) 8 days of food intake data after weaning, and iii) 8 months of morbidity data. Second, children were required to have weight and length measures taken at 30 months $\pm$ 30 days and 30 months $\pm$ 45 days respectively. This resulted in sample sizes of 71 (weight) and 67 (length). For comparability, analyses were restricted to 67 cases with complete data for weight and length (35 girls and 32 boys).

Outcome, predictor and control variables were constructed from the longitudinal data. The outcome variables are i) weight and length at 30 months, and ii) weight and length slopes (growth rates) estimated for each child by OLS linear regression of weight and length on age during 18 to 30 months. Weight and length at exactly 18 months were estimated using these regression equations, then converted to Z scores using a Center's for Disease Control algorithm.

Food intake variables were calculated from mean daily intakes between 18-30 months of age, after complete weaning. (Eleven of the 67 children were not completely weaned by 18 months but all were weaned by 26 months). Nutrient intake variables used are: i) kcal/d and g protein/d; and ii) kcal and g protein per kg body weight, with weight on each day of intake estimated from a regression of weight on age; iii) kcal/d and g protein/d from animal sources, and % kcal and % protein from animal sources (dietary quality markers).

Morbidity variables are the ratio of days ill to days observed for the following illness categories: total illnesses, diarrhea, fever, acute lower respiratory, acute upper respiratory (excluding runny nose), and runny nose.

Maternal variables are mean weight, height, BMI (weight/height^2), and age. Data were only used in these analyses if they were recorded during the non-pregnant, non-lactating state.

The environmental predictor variables include measures of household demographic characteristics (household size, number of adult and teenage women, and number of children under 12 years) and indices of household socioeconomic status.

Pearson's product-moment correlations were used in correlation analyses with the exception of the morbidity variables, where Spearman's rank-order correlations were employed because of the large number of zero (no illness) values. OLS regression (PROC REG) was used for the regression models. Throughout the analytic process, many of the principles and techniques of exploratory data analysis were employed [2,3].

Size of the Children

Results are presented systematically for the two types of anthropometric outcomes: *attained size* (weight, length) at 30 months, and *growth rates* (slopes of weight and length) between 18 and 30 months.

Attained Size at 30 Months

The median weight-for-age Z-score was -1.2 (range -3.1 to 1.1) while that for length-for-age was -1.8 (range -3.6 to 0.7) (Table 14.1). Thus, as for the entire group of preschoolers, this sample was growth-stunted on average although some children were of normal weight and/or length. Weight and length Z-scores at 30 months were highly correlated ($r=0.79$, $p=0.001$) and weight-for-length was generally close to NCHS reference values.

Because Solís Valley children are growth-retarded before the age of 18 months, any associations with small size at 30 months reveal the cumulative effects of diet, morbidity, and environment since birth. This is illustrated by the high correlations between weight at 18 and 30 months ($r= 0.72$, $p<0.0001$) and length at 18 and 30 months ($r=0.84$, $p<0.0001$), showing size at 30 months to be strongly predetermined by prior size at 18 months.

Weight and Length Growth

To restrict analyses to growth during the 18 to 30 months research period, individual growth slopes were calculated from a mean of 12.8 weight (range 6 to 17) and 4.0 length measures (range 3 to 6). The resulting weight slopes ranged from -0.67 to 3.93 kg/year with a mean of 2.13 kg/year (Table 14.1). Two subjects, one male and one female, had negative slopes i.e. actually lost weight during this year. Mean length slope was 8.83 cm/year (range 3.57 to 14.40). For U.S. children of this age, the equivalent mean values are approximately 2.3 kg/year and 10 cm/year so that the mean rates of preschooler growth in Solís children were near the 50th percentile for weight and 25th percentile for length. However, approximately 25% of children were growing at rates below the 10th percentile for weight and the 3rd percentile for length.

Weight and length slopes also had sizeable negative correlations with their intercepts at 18 months (for weight, $r=-0.33$, $p=0.006$; for length, $r=-0.40$, $p=0.0007$), suggesting that smaller children at 18 months grew more rapidly than did larger children between 18 and 30

Table 14.1: Annual weight and length slopes, and 30 month Z-scores (N=67).

	Mean	SD*	Q1†	Median	Q3‡
Weight Z, 30 mo	-1.24	0.90	-1.79	-1.21	-0.75
Length Z, 30 mo	-1.82	0.99	-2.48	-1.85	-1.08
Weight Slope (kg/y)	2.13	1.01	1.41	2.22	2.92
Length Slope (cm/y)	8.83	2.31	7.03	8.95	10.09

* SD = standard deviation
† Q1 = lower quartile (25th percentile)
‡ Q3 = upper quartile (75th percentile)

months. In part, these negative correlations are artifacts induced by the correlation of the estimated intercept with the slope in the individual regression equations (4). The correlation of weight slope with mean weight (which is equivalent to the midpoint of the line) was positive (r=0.22), while that for length slope and mean length was low and negative (r=-0.09). As these mid-point correlations avoid the induced relationship between slope and intercept, they support the possibility that the negative correlations between slopes and 18 months intercepts are artifacts of the slope fitting procedure.

Relationship of Intake to Attained Size and Growth Rate

Table 14.2 provides descriptive statistics for the mean daily intakes of energy and protein for weaned children between 18 and 30 months of age, calculated from a mean of 17 (range 8 to 26) days of food intake data on each child. T-tests showed there were no significant sex differences for any intake variable so that male and female data were combined for the following analyses. The mean intake of energy was 101 kcal/kg and that of protein was 3.1 g/kg. Thus, as for the larger sample, based on WHO/FAO/UNU recommended intakes (102 kcal/kg for girls, 104 kcal/kg for boys, and 1.2 g protein/kg for both sexes) [5], dietary energy and protein was sufficient on average for this sample. However, mean intakes of dietary energy (12.1%) and protein (26.3%) from animal sources were very low, with 19.4% of children obtaining less than 5% of kcal from animal products on recall days. Calculation of essential amino acid intakes showed that requirements for these were met [6]. Dietary protein and energy are highly correlated (r=0.92, p=0.0001) and therefore nearly indistinguishable statistically.

Table 14.2: Distribution of mean daily intakes of energy and protein between 18 and 30 months of age (N=67).

	Mean	SD	Q1	Median	Q3
Kcal/d					
Total	1081.8	264.2	909.8	1048.0	1207.2
Animal	125.5	91.5	61.4	105.7	156.2
Protein g/d					
Total	32.6	7.9	27.2	31.9	38.4
Animal	9.0	5.8	4.6	7.8	11.9
Kcal/kg					
Total	101.3	27.8	80.1	99.8	118.8
Animal	11.5	7.7	5.8	9.7	14.3
Protein g/kg					
Total	3.0	0.80	2.3	3.1	3.6
Animal	0.83	0.49	0.49	0.72	1.08
% Animal kcal	12.1	9.2	6.6	9.2	15.3
% Animal Protein	26.3	15.0	16.2	22.7	34.8

• SD = standard deviation

Attained Size at 30 Months.

Table 14.3 includes the Pearson correlations of the 18 to 30 month mean food intake measures with Z-scores for weight and length at 30 months. Total energy and protein intakes were not significantly correlated with size at 30 months, but dietary quality variables (total and percent energy and protein from animal sources) had significant positive correlations with both attained weight and length.

One surprising result in Table 14.3 is the sizeable negative correlation of attained size with energy (and protein) intake when expressed per kg body weight. Further analyses showed children's mean daily kcal intake between 18 and 30 months to bear no relationship to their weight quartile position at 24 months and 18 months (not shown) which explains why expressing kcal intake on a per kg basis produced apparently lower intakes in the larger children. In contrast, animal kcal and protein intake (not shown) was higher with each weight

Table 14.3: Correlations of intake variables with Z-scores and with growth slopes (N=67).

	Weight		Length	
	Z-score	Slope*	Z-score	Slope
Kcal/d				
Total	-0.09	0.18	-0.10	-0.10
Animal	0.30†	0.22	0.36‡	0.09
Protein g/d				
Total	0.05	0.28†	0.06	-0.08
Animal	0.28†	0.29†	0.33§	0.12
Kcal/kg				
Total	-0.43 ‖	0.09	-0.40 ‖	-0.08
Animal	0.17	0.20	0.24†	0.09
Protein g/kg				
Total	-0.32§	0.17	-0.28†	-0.07
Animal	0.13	0.26†	0.18	0.12
% Animal kcal	0.34‡	0.18	0.38‡	0.15
% Animal Protein	0.32§	0.23	0.35‡	0.17

* Residual weight slope controlling for the mean age at weight measures.
† $p<0.05$ ‡ $p<0.005$ § $p<0.01$ ‖ $p<0.001$

quartile and remained positively significantly (ANOVA, $p<0.05$) associated with size when expressed on a per kg basis.

Weight and Length Slopes.

As shown in Table 14.3, mean daily energy intake was not significantly related to the annual rate of either weight or length increase. In contrast, mean daily consumption of total protein, and also of protein from animal sources, was significantly correlated with weight slope. No significant correlations were seen between the rate of length increase and either the nutrient intake or dietary quality variables.

Relationship of Morbidity to Attained Size and Growth Rate

Morbidity data were collected over 42 weeks on average (range 24 to 49 weeks). Illness was reported in 75% of the male and 83% of the female children over the year. Because the distribution of the morbidity data was skewed, some children having no reported illness, associations between illness variables and growth rates were explored through Spearman rank-order correlations (Table 14.4). However, Pearson product-moment correlations produced a virtually identical pattern of significant associations (not shown).

Attained Size at 30 Months.

In general, there was a tendency for larger children at 30 months to have more reported illness during the preceding 12 months. Taller children had significantly more reported total illness, lower respiratory infections, and a tendency to more reported illness in general (Table 14.4). Heavier children tended to have somewhat more reported total illness between 18 and 30 months.

Weight and Length Slopes.

Most illness categories showed little relationship to rate of weight growth (Table 14.4), with the exception that children who experienced more diarrhea tended to gain weight more slowly ($r=-0.24$, $p=0.03$). Also, children grew more slowly (1.84 kg/year) if they had suffered at least one episode of diarrhea, compared to those with no episode (2.34 kg/year, $p=0.06$). In contrast to weight growth, the rate of length increase was not significantly correlated with illness, although mean length slopes were lower (7.74 cm/year) for children who had some reported illness compared to those who were recorded as being healthy throughout the year (9.12 cm/year, $p=0.04$).

Child's Age at Weaning vs Attained Size and Growth Rate

The approximate age when breast feeding stopped was reported by the mother, and tested for any relationship to growth between 18 and 30 months. Almost all children (84%) were weaned by 18 months (mean=11.2 months, range 0 to 26 months), and in most cases solid food would have been introduced well before weaning. The weaning age of the children was negatively correlated with length Z-scores ($r=-0.30$, $p=0.01$), but not with weight Z-scores, showing a tendency for shorter children at 30 months to have been weaned at an older age. In contrast, the age of weaning was unrelated to the rate of growth in weight and length between 18 and 30 months.

Table 14.4: Spearman correlations for % days ill with attained size at 30 months and with growth slopes (N=67).

Illness	Weight Z-score	Weight Slope*	Length Z-score	Length Slope
Total	0.21	-0.07	0.36†	0.13
Diarrhea	0.04	-0.24	0.23	0.04
Fever	0.20	0.03	0.21	-0.02
Lower Respiratory	0.12	-0.09	0.27‡	0.17
Upper Respiratory	0.06	0.07	0.19	-0.02
Runny Nose	0.16	-0.13	0.22	-0.06

* Residual weight slope controlling for mean weight age
† $p<0.005$
‡ $p<0.05$

Maternal Size vs Attained size and Growth Rate.

Solís Valley mothers were short by U.S. standards (mean = 152 cm, range 144 to 165). Mean maternal weight was 60 kg (range 46 to 101). The body mass index (BMI) for these mothers was somewhat higher than the average for U.S. women (Solís mean = 25.5, range 19.7 to 45.2).

Mother's size predicted their child's size at 30 months. Overall, heavier and taller children tended to have taller, heavier, and, in the case of weight, fatter mothers (Table 14.5). Heavier mother's children grew faster in length, but weight growth was unrelated to how heavy or tall she was.

The Child's Environment vs Attained Size and Growth Rate.

Neither attained size, nor weight or length growth, were related to household size, number of adult or teenage women, the number of children in the household, or maternal age. However, the smallest children at 30 months of age were more likely to come from homes which were poorer, and had a non-literate mother (Table 14.5).

For growth rates, the best environmental predictors were mother's literacy and socioeconomic status (Table 14.5). The children of literate mothers grew more rapidly than those of non-

Table 14.5: Correlations of maternal and environmental variables with attained size at 18 months and with growth slopes (N=67).

Variable	N	Weight Z-score	Weight Slope*	Length Z-score	Length Slope
Maternal Weight	67	0.38†	0.13	0.30‡	0.28‡
Maternal Height	67	0.28‡	0.17	0.33§	0.14
Maternal Wt for Ht^2	67	0.27‡	0.11	0.16	0.03
Maternal Head Circum.	67	0.29‡	0.08	0.32§	-0.02
Number of Children	65	-0.19	0.00	-0.20	-0.03
Mother's Literacy	62	0.34§	0.13	0.37†	0.26‡
Socioeconomic Status	62	0.35§	0.23	0.45 ‖	-0.04

* Residual weight slope controlling for weight age.
† $p<0.005$ ‡ $p<0.05$ § $p<0.01$ ‖ $p<0.001$

literate mothers. Mean growth rates were faster, 2.23 kg/year and 9.23 cm/year for children with literate (N=47) mothers compared to 1.93 kg/year and 7.79 cm/year (N=15) for those whose mothers were non-literate (p=0.02 for length). Also, variability in the children's length slopes was higher if the mother was more literate: the variance was 2.2 for the illiterate group vs. 6.3 for the literate (p=0.02). This shows a broader range of growth rates for literate mothers than seen for non-literate. The literate mothers were themselves taller (153.2 cm) than the illiterate (150.9, p=0.07).

Weight slope had a marginally significant correlation with SES ($p<0.10$), higher SES children tending to grow faster in weight, but not length.

Interactive Effects of Maternal Size and Child's Diet on Size at 30 Months

In the correlation analyses described above, several variables were identified as good predictors of child growth and size. Maternal size not only predicted size at 30 months, and rate of weight growth between 18 and 30 months (Table 14.5), it was also significantly related to weight at 18 months (r=0.33, p=0.007). Thus, initial multivariate analyses focused on the relationship of both child diet and maternal size to size at 30 months. Animal kcal intake was chosen to represent dietary quality. A natural log transformation of this variable was employed in all regression analyses below as a method of straightening relationships and improving a skewed distribution [7]. Because animal protein intake is highly correlated with animal kcal, this variable was not used in the analyses presented here. However, animal protein produced similar results to animal kcal.

Weight Z-score at 30 Months.

In the bivariate analyses, maternal weight was the best maternal predictor of weight at 30 mo. Dividing our sample into four groups by quartile of animal kcal intake (eliminating two obese mothers for presentation purposes), the relationship between maternal weight and weight Z-score was plotted (Figure 14.1). These plots suggest an interaction between maternal size and the child's mean animal kcal intake in predicting attained size. For the lower animal kcal groups, little relationship is seen between maternal weight and child weight (first quartile, r=-0.08, n.s., N=16; second quartile, r=0.15, n.s., N=17). However, much stronger positive relationships are seen when animal kcal intake is higher (third quartile, r=0.37, n.s., N=17; fourth quartile, r=0.81, p=0.0001, N=17), the children of heavier mothers being heavier when they consume more animal origin foods. Plots (not shown) also show children of lighter mothers to exhibit little effect of animal kcal intake while those of heavier mothers show a response. This is because the smallest size is predicted by low animal kcal intake in combination with a lighter mother. There were no similar interactive effects between maternal size and either the non-animal dietary variables or social variables.

Multiple regression was used to model this interaction effect, using the cross-product of log animal kcal and maternal weight (Table 14.6). Influence statistics had suggested the elimination of two children of obese mothers (90 and 101 kg) and another highly influential case (a child with extremely low animal kcal intake and relatively few dietary recalls), resulting in a sample of 64 cases. Table 14.6 shows the regression model (Model 2), which confirms an interaction between animal kcal intake and maternal weight, higher consumption of animal foods enhancing the positive effect of maternal weight on attained weight at 30 mo.

Length Z-score at 30 Months.

As with the weight Z-scores, plots suggested an interaction between maternal weight and her child's animal kcal intake in predicting 30 months length (Figure 14.2). Similar to weight Z-score, the highest quartile of animal kcal intake had a high correlation between maternal weight and child length (r=0.63, p=0.01, N=17), indicating the greater length of children of heavie nothers. Intermediate intakes of animal kcal produced lower correlations (third quartile, r=0.28, n.s., N=17; second quartile, r=0.25, n.s., N=17), while the length of children with lowest consumption of animal products was negatively correlated with maternal weight (r=-0.31, n.s., N=16).

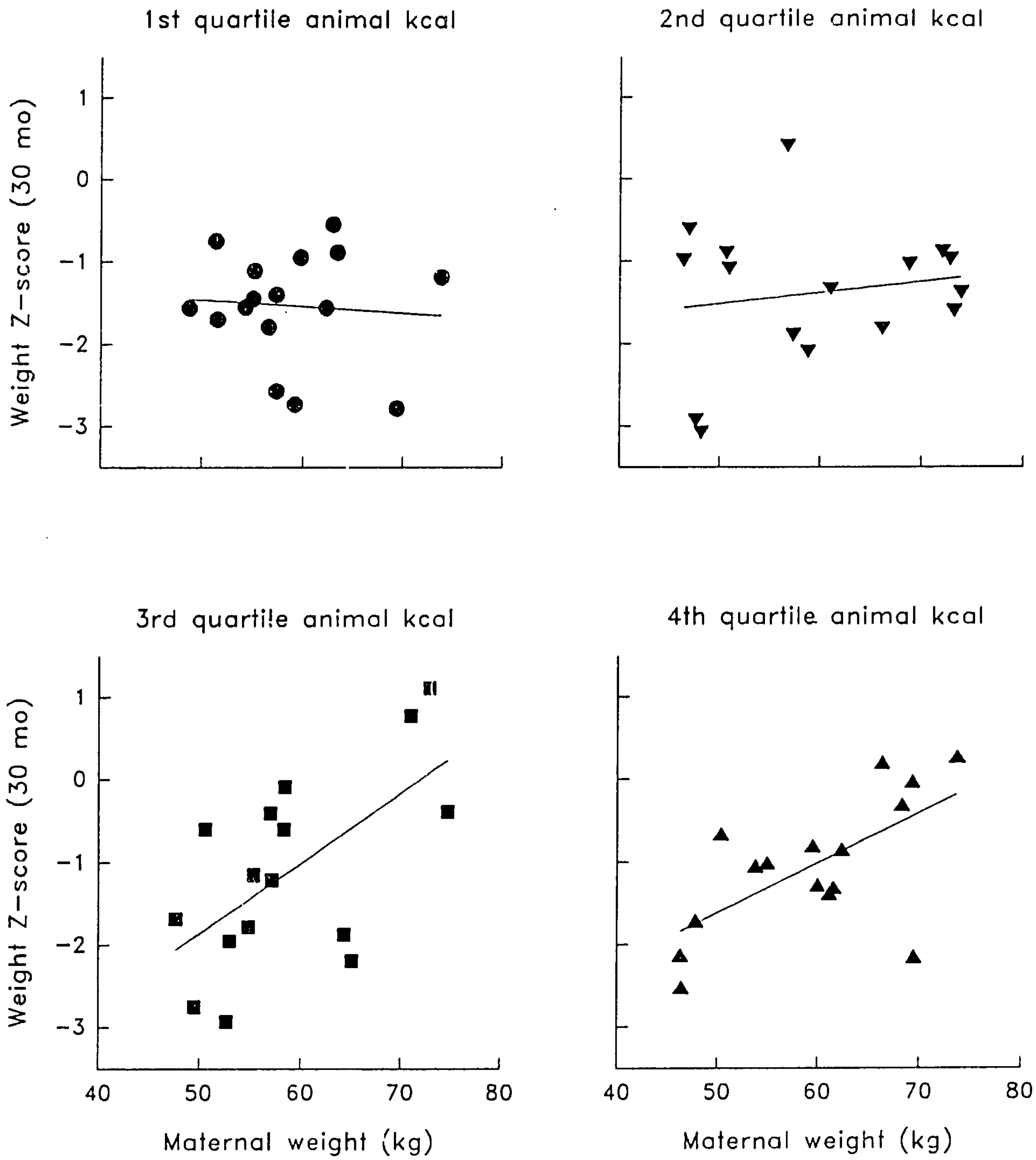

Figure 14.1: Maternal weight (kg) and weight Z-score at 30 months by quartile of animal kcal intake. OLS regression line is shown for each quartile group.

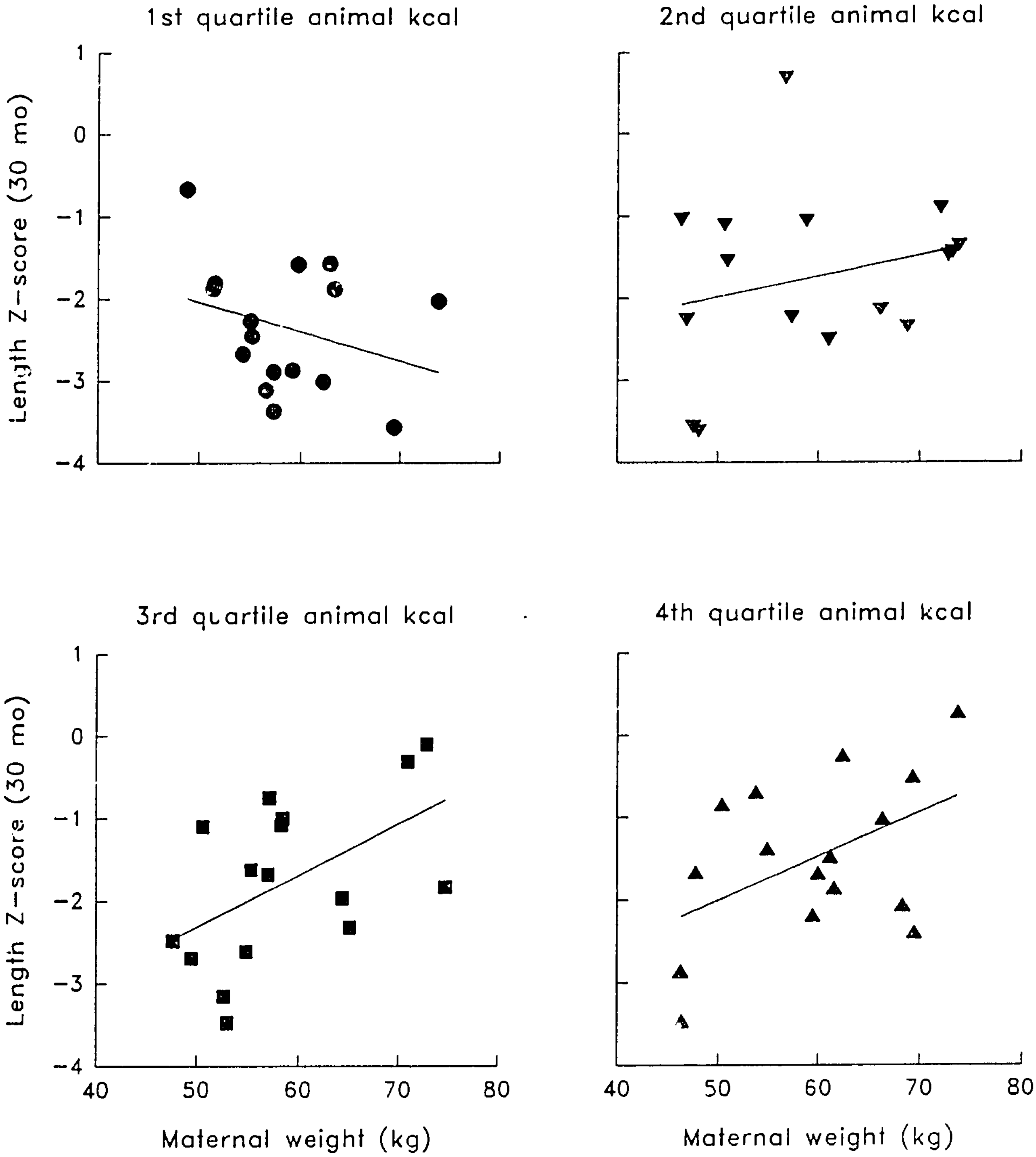

Figure 14.2: Maternal weight (kg) and length Z-score at 30 months by quartile of animal kcal intake. OLS regression line is shown for each quartile group.

Table 14.6: Multiple regression model for attained size at 30 Months: the effects of animal kcal intake and maternal weight.

	Variables	Weight: Parameter Estimate	Weight: t Statistic	Weight: p-value	Length: Parameter Estimate	Length: t Statistic	Length: p-value
Model 1	Intercept	-4.795	-4.72	0.0001	-5.685	-5.05	0.0001
(N=64)	Maternal Weight (kg)	0.038	3.04	0.0035	0.032	2.31	0.0243
	Log Mean Animal kcal (g)	0.281	1.73	0.0883	0.427	2.37	0.0209
Model 2	Intercept	8.059	1.44	0.1557	8.604	1.38	0.1715
(N=64)	Maternal Weight (kg)	-0.179	-1.91	0.0610	-0.210	-2.01	0.0488
	Log Mean Animal kcal (g)	-2.467	-2.07	0.0425	-2.628	-1.99	0.0511
	Maternal Wt*Log Animal kcal	0.046	2.33	0.0232	0.052	2.34	0.0229

	Weight	Length
Model 1	R-Square = 0.18	R-Square = 0.16
	Root MSE = 0.83	Root MSE = 0.92
Model 2	R-Square = 0.24	R-Square = 0.23
	Root MSE = 0.80	Root MSE = 0.89

Using the same cases as in the weight analyses, the multiple regression model again showed an interaction between maternal weight and log animal kcal intake, the magnitude and direction of the relationships being very similar to that seen for weight (Table 14.6, Model 2). As seen for weight Z-score at 30 months, less consumption of animal origin foods weakened the relationship between a mother's weight and the length of her child. Influence statistics suggested the elimination of two outliers which strengthened the model and raised the R-square from 0.23 to 0.33 (not shown).]

Additional Effects of Weaning, Morbidity, and Environment on Size at 30 Months

Multiple regression models were constructed to investigate the additional effects of morbidity, weaning, and environment on child size. As seen in the bivariate analyses, the morbidity variables continued to be positively associated with both child weight (Table 14.7, Model 1) and length (not shown), higher reported morbidity being associated with larger size. The environmental variables, SES and maternal literacy, show similar results for both weight and length Z-scores. SES weakens the effects of maternal weight and animal product consumption on attained size, while being a poor predictor of weight and length Z-scores (not shown). Maternal literacy is a somewhat better predictor, literate mothers having larger children, while maternal size and animal kcal consumption remain good predictors of child weight (Table 14.7, Model 2). However, maternal literacy was a marginal predictor of length at 30 months (not shown). The inclusion of age at weaning did not improve the animal kcal/maternal weight model for weight Z-score. However, older age at weaning was associated with shorter length at 30 months taking into account maternal weight and animal kcal consumption (not shown).

The Relationship of Size to Weight and Length Slopes

As described above, mean weight between 18 and 30 months was positively correlated with weight slope during the same period, while there was little relationship between mean length during this period and length slope. Multiple regression shows a tendency for heavier and, to a lesser extent, shorter children to grow faster in weight than did children who were lighter or taller (Table 14.8). In contrast to weight growth, length growth rate between 18 and 30 months showed little relationship to the mean size of the child during this year.

Table 14.7: Multiple regression models for weight Z-scores at 30 months.

	Variables	Parameter Estimate	t Statistic	p-value
Model 1	Intercept	7.143	1.32	0.1932
(N=63)	Maternal Weight (kg)	-0.169	-1.86	0.0673
	Log Mean Animal kcal (g)	-2.265	-1.97	0.0539
	Maternal Wt*Log Animal kcal	0.043	2.25	0.0285
	% Days of Illness	0.045	2.08	0.0420
Model 2	Intercept	7.265	1.27	0.2106
(N=59)	Maternal Weight (kg)	-0.172	-1.81	0.0755
	Log Mean Animal kcal (g)	-2.460	-2.00	0.0509
	Maternal Wt*Log Animal kcal	0.044	2.20	0.0317
	Mother's Literacy	0.480	1.79	0.0789

Model 1: R-Square = 0.29 Root MSE = 0.77
Model 2: R-Square = 0.31 Root MSE = 0.77

Table 14.8: Multiple regression models for growth slopes during 18 to 30 months as predicted by mean weight and length.

	WEIGHT			LENGTH		
Variables	Parameter Estimate	t Statistic	p-value	Parameter Estimate	t Statistic	p-value
Intercept	2.634	0.78	0.4394	20.120	2.46	0.0165
Mean Wt 18-30 mo (kg)	0.437	2.27	0.0269	0.592	1.22	0.2253
Mean Lgth 18-30 mo (cm)	-0.109	-1.83	0.0722	-0.223	-1.48	0.1447
Mean Age at Wt Measures	0.524	3.48	0.0009			

Weight
R-square: 0.25
Root MSE: 0.91

Length
R-square:0.03
Root MSE:2.30

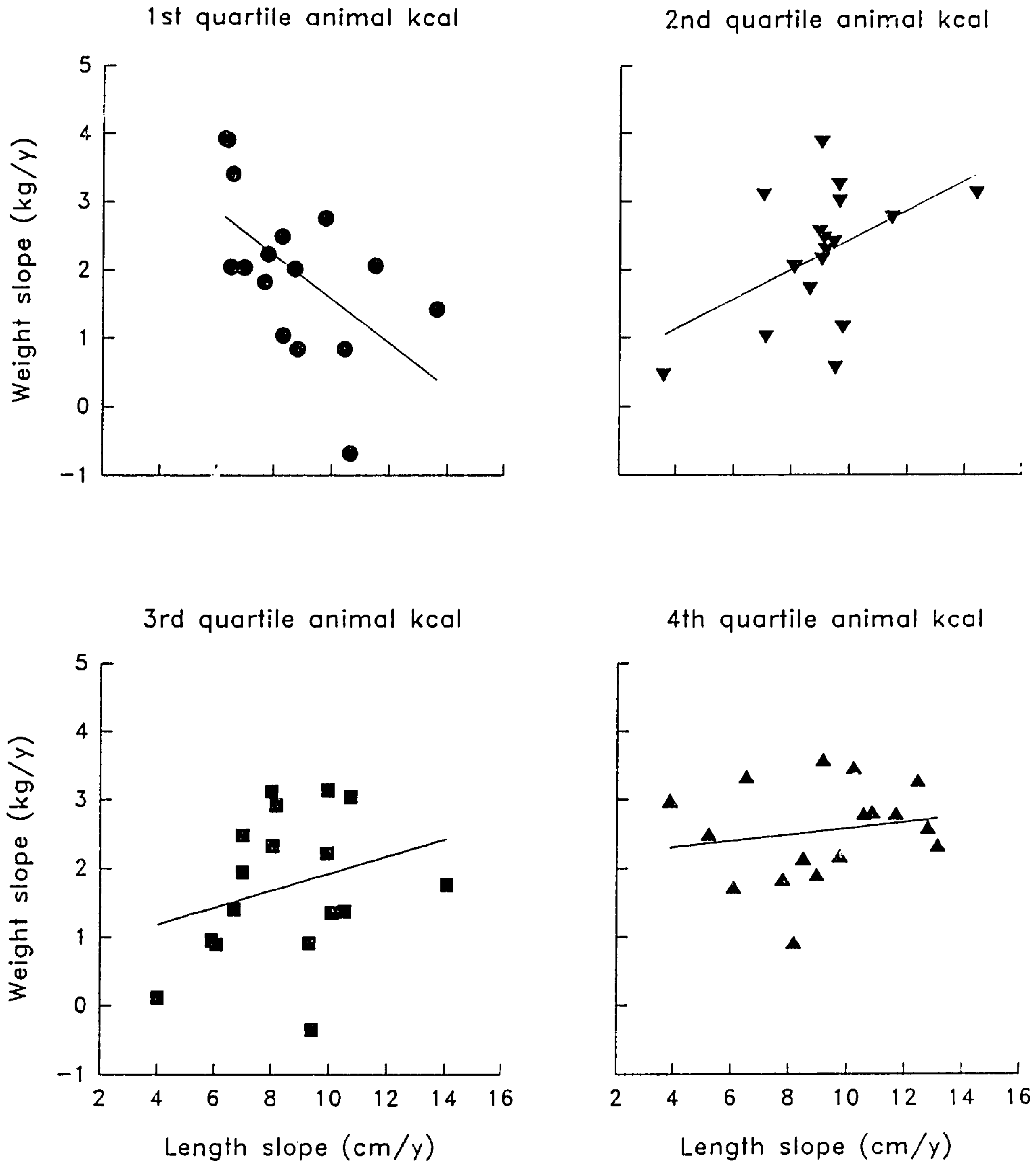

Figure 14.3: Weight slope (kg/year) vs length slope (cm/year) by quartile of animal kcal intake.

Animal Products Affect the Relationship Between Weight and Length Slopes

While the correlation between weight Z-score and length Z-score at 30 months was high ($r=0.79$, $p=0.0001$, $N=67$), there was a low correlation ($r=0.10$, n.s., $N=67$) between rates of length and weight growth during the 18 to 30 month period. Dividing the sample into four groups (as before) by quartile of animal kcal intake, differences in the relationship between weight and length growth are seen according to intake of animal kcal (Figure 14.3). Children in the lowest quartile of animal kcal intake show faster length growth to be associated with slower weight growth (first quartile: $r=-0.57$, $p=0.02$, $N=16$). In contrast, groups with higher animal kcal consumption (above 61 kcal/d) have positive correlations between rates of weight and length growth (second quartile, $r=0.48$, $p=0.05$, $N=17$; third quartile, $r=0.28$, n.s., $N=17$; fourth quartile: $r=0.17$, $p=0.50$, $N=17$). Multivariate models confirmed the existence of an interactive effect of animal kcal with rates of length and weight growth (Table 14.9). In Model 1, weight growth rate was not related to either length growth rate or animal kcal consumption. However, the inclusion of an interaction term (cross-product) for log animal kcal and length growth rate (Table 14.9, Model 2) shows both variables in combination to be important in describing weight growth. As with the attained size analyses, only the animal intake variables behaved in this statistical manner. These results suggest that coordinated length and weight growth may be dependent on the quality of their diet.

The Effects of Maternal Size and Child Diet on Growth Rates

Weight Slopes.

Plots of maternal weight and child weight slope by quartile of animal kcal consumption (Figure 14.4) suggest that weight gain may be affected by an interaction between maternal size and animal kcal consumption (as was the case with the Z-scores). The correlation between maternal weight and weight slope was strongest for the high animal kcal quartile (first quartile: $r=-0.50$, $p=0.05$, $N=16$; second quartile, $r=0.11$, n.s., $N=17$; third quartile: $r=0.07$, n.s., $N=17$; fourth quartile: $r=0.43$, $p=0.08$, $N=17$). Using the same cases in the attained size regressions, multiple regression models (controlling for mean size and the mean age at time of weight measurements) showed neither maternal weight nor animal kcal intake to be good predictors of weight growth rate either as main effects or as a cross-product (not shown).

Table 14.9: Multiple regression models for weight slope during 18 to 30 months as predicted by length slope.

	Variables	Parameter Estimate	t Statistic	p-value
Model 1	Intercept	1.320	1.34	0.1849
(N=64)	Length Slope (cm/y)	0.068	1.17	0.2478
	Log Mean Animal kcal	0.041	0.20	0.8435
Model 2	Intercept	11.568	3.12	0.0027
(N=64)	Length Slope (cm/y)	-1.066	-2.66	0.0099
	Log Mean Animal kcal	-2.179	-2.72	0.0085
	Length Slope*Animal kcal	0.244	2.86	0.0058

Model 1: R-Square = 0.03 Root MSE = 1.02
Model 2: R-Square = 0.14 Root MSE = 0.96

Table 14.10: Multiple regression model for length slope during 18 to 30 months: the effects of animal kcal intake and maternal weight.

	Variables	Parameter Estimate	t Statistic	p-value
Model 1	Intercept	3.696	1.34	0.1840
(N=64)	Maternal Weight (kg)	0.076	2.26	0.0277
	Log Mean Animal kcal (g)	0.137	0.31	0.7561
Model 2	Intercept	10.245	0.65	0.5201
(N=64)	Maternal Weight (kg)	-0.035	-0.13	0.8959
	Log Mean Animal kcal (g)	-1.263	-0.38	0.7086
	Maternal Wt*Log Animal kcal	0.024	0.42	0.6760

Model 1: R-Square = 0.08 Root MSE = 2.25
Model 2: R-Square = 0.08 Root MSE = 2.26

Length Slopes.

The correlation of maternal weight with length slope was near zero for the low animal kcal group (first quartile: r=0.06, n.s., N=16) and for the moderately high animal kcal group (third quartile, r=0.10, n.s., N=17). In contrast, correlations were strongly positive for both the high animal kcal group and the moderately low animal kcal group (fourth quartile, r=0.45, p=0.07, N=17; second quartile, r=0.47, p=0.06, N=16).

Multiple regression modeling showed the presence of a positive main effect on length slope by maternal weight, children of heavier mothers growing at faster in length (Table 14.10, Model 1). However, a second model suggested no interaction between animal kcal and maternal weight (Table 14.10, Model 2).

The Additional Effects of Weaning, Morbidity and Environment on Growth Rates

Age at weaning showed no additional effect on rates of either weight or length gain (not shown). With the exception of diarrhea, the morbidity variables were poor predictors of both weight and length growth. However, more diarrhea was associated with slower weight growth (Table 14.11, Weight model), while being a poor predictor of length growth (Table 14.11, Length model 1).

The environmental variables failed to alter substantially the relationships of maternal weight and animal kcal intake to child growth. For the weight slopes, neither SES nor maternal literacy are good predictors when added to the model (not shown). In the case of length, SES is a relatively poor predictor of growth, while maternal literacy is a somewhat stronger one, weakening the effect of maternal weight (Table 14.11, Length model 2).

Summary of Preschooler Growth Predictors

In Chapter Five, infants from these communities were shown to have a size at birth close to international norms, but substantial growth faltering relative to NCHS reference values occurred by around 3 months of age. No longitudinal data were collected by the CRSP between 8 and 18 months. Growth failure continues to about 30 months (Chapter 5), so that by 30 months children have severe deficits in weight and length. Size at this age is strongly predetermined by prior size at 18 months. In this sample 70% of the variance in 30 month weight and 49% of the variance in 30 month length was explained by 18 month weight and length respectively. Growth between 18 and 30 months was at or near U.S. reference values for most children. However, approximately 25% of children showed signs of substantial, continued growth failure during this period, growing below the 10th percentile for weight and the 5th percentile for length. Taken together, the infant and preschooler results suggest that while most growth

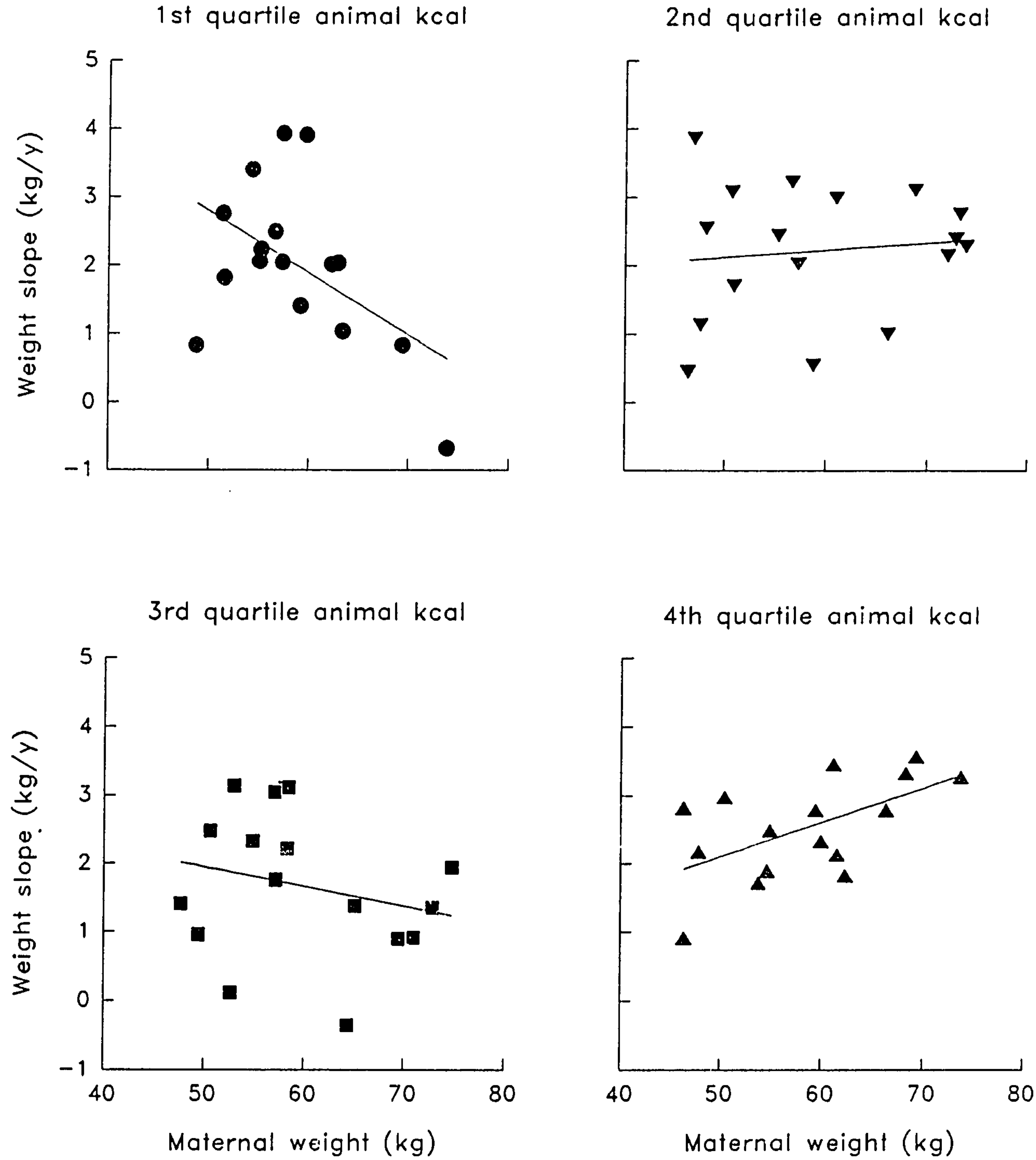

Figure 14.4: The relationship between weight slope (kg/year) and maternal weight (kg) by quartile of animal kcal intake.

Table 14.11: Multiple regression model for weight slope during 18 to 30 months.

	Variables	Parameter Estimate	t Statistic	p-value
WEIGHT	Intercept	2.263	0.77	0.4446
(N=63)	Mean Weight 18-30 mo (kg)	0.507	3.00	0.0039
	Mean Length 18-30 mo (cm)	-0.115	-2.22	0.0303
	Mean Age at Wt Measures (mo)	0.564	4.29	0.0001
	% Days with Diarrhea	-0.100	-2.15	0.0357
	R-Square = 0.38	Root MSE = 0.79		
LENGTH	Intercept	4.341	2.16	0.0345
Model 1	Maternal Weight (kg)	0.076	2.28	0.0264
(N=64)	% Days with Diarrhea	-0.030	-0.23	0.8159
Model 2	Intercept	2.475	1.07	0.2892
(N=59)	Maternal Weight (kg)	0.069	1.99	0.0519
	Maternal Literacy	1.294	1.91	0.0610

Model 1: R-Square = 0.08 Root MSE = 2.25
Model 2: R-Square = 0.13 Root MSE = 2.26

faltering in this population occurs prior to 18 mo, in some children the process continues well past the age of 18 months. Therefore, the preschooler period in this population appears to be a time during which individuals experience varying degrees of growth maintenance, catch-up, or further faltering. The high variability in growth rates may be an indicator of environmental stress [8].

The Effects of Morbidity

Our analyses show some negative effects of morbidity on growth during 18 to 30 months: slower weight growth was associated with more diarrhea, while length growth was slower for children experiencing some illness during the study period. In contrast, puzzling relationships emerged between morbidity and attained size, higher morbidity being associated with larger weight and length at 30 months. Several explanations of this paradoxical result seem possible. First, larger children may actually become ill more often than smaller children. Structured observation data on a subsample of 33 of these preschoolers showed larger children to be much more physically active than smaller ones (Chapter Sixteen). In an unsanitary environment, this may result in higher morbidity and explain a positive relationship between morbidity and 30 month size, and a negative one with rate of growth between 18 and 30 months. Secondly, error in the measurement of morbidity must be considered. Analyses in Chapter Nine show higher maternal competence to be associated with higher reported preschooler respiratory illness. Therefore, the potential exists for socially-based variation in the classification and reporting of preschooler morbidity by mothers. In addition, the Mexico CRSP morbidity protocol, as noted in Chapter Nine, is biased against the detection of short term illnesses. Moreover, the illness categories imperfectly model any illness processes that may affect growth.

The Effects of Diet

The small size and growth of these children do not appear to result from inadequate intakes of energy and protein. Energy and protein intake during this period were unrelated to size, so that the intakes of smaller children were higher on a per kg basis. This has been observed previously by others [9]. Rather than dietary quantity, the current analyses strongly suggest a role for better quality diets in fostering growth at some time prior to 30 months. This is perhaps not surprising given the high prevalence of micronutrient deficiencies in these children, especially in those consuming poor quality diets (Chapter Eight). Higher consumption of foods of animal origin is associated with children being heavier and taller at 30 months controlling for morbidity, SES, and maternal literacy. However, while being good predictors of attained size, the dietary variables are poor predictors of growth during the 18 to 30 month period. These results suggest that the main effect of dietary quality occurs prior to 18 months assuming that those children who were given better quality diets after 18 months also received them prior to this age. However, further analyses showed that rates of weight and length growth during 18 to 30 months tend to be parallel except when consumption of animal kcal is very low. In this case, there is an inverse relationship between weight and length growth. Thus adequate growth in both weight and length is contingent on better dietary quality, and dietary quality plays a continuing, subtle role in growth during 18 to 30 months.

Similar interactive effects of dietary quality are seen in the relationship between maternal weight and attained size at 30 months. In general, maternal weight is a good predictor of attained size at 30 months. However, children with the poorest quality diets show little relationship between their size and their mother's weight. In the case of growth rates, bivariate analyses show children of heavier mothers to grow faster in length. As with attained size, there is a suggestion that animal product consumption has an interactive effect, the children with the best quality diets showing strong relationships between maternal weight and rates of growth, while children with poorer diets showed negative or low correlations between maternal weight and growth rates. A child who does not eat an adequate diet will not benefit from having a larger mother. Multivariate analyses were less successful at modeling these interactions with growth rate than was the case for attained size, perhaps due to difficulties in modeling threshold effects using assumptions of linearity. An examination of the lowest animal quartile group shows the weaker relationship of growth with maternal weight to be due, in part, to children who are growing faster in just one parameter (weight or length) than would be expected given maternal size, while their growth in the other parameter is much slower.

In Chapter Eleven, relationships between maternal and child size were also evident in early infancy, before significant quantities of non-breastmilk foods are fed. We believe that the relationships of maternal size to child growth and attained size reflect a complex of influences, including the shared genetics of the mother and child, prior nutritional effects on the child via pregnancy and lactation, and, possibly, unmeasured characteristics of the shared household environment.

In summary, these analyses suggest a failure, by some children, to maintain integrated growth in weight and length as a result of poor quality diets. The interpretation of these results is complicated by the local food consumption pattern. In Chapter Six, we showed increased consumption of animal foods to be associated with both a decreased reliance on *tortillas*, and a general improvement and diversification of the diet. Therefore, the apparent positive effects of higher consumption of animal products may be due to general improvements in the diet, resulting in higher intakes of several nutrients and decreased consumption of phytates and fiber that reduce nutrient bioavailability. Until the specific nutrients limiting growth in this population are identified, the variable "animal kcal" should be interpreted as a proxy for a diet that is higher in quality, contains relatively more animal products and fewer *tortillas*, and is generally more diversified. The poor quality of the Solís Valley diet is also indicated by the high prevalences of anemia, iron deficiency and vitamin B_{12} deficiency among these children (Chapter Eight).

Our results suggest an additional strategy for the detection of nutrition-related growth failure during early life. Rather than focus exclusively on the linear effects of dietary variables on growth and size, it may be important to look for differences in the relationships of growth and size to independent variables according to dietary intake (interactions). Our initial efforts at exploring interaction were prompted by the surprisingly poor correlation between the annual rates of weight and length gain. The potentially disruptive or facilitating effects of the diet, morbidity, and environmental variables were investigated. Only the animal intake variables showed an interactive effect with weight and length growth. These results, combined with the interactive effects of maternal weight and animal product intake on size at 30 months (and possibly length growth), suggest the potential usefulness in other populations of examining differences in growth with respect to different levels of dietary quality.

Investigators of child growth determinants frequently assume that weight and length can be used interchangeably as outcomes. However, from the analyses presented here it is apparent that using either weight or length gain data alone would identify different children as growing slowly, especially when dietary quality is poor. It also follows that differing rates of weight growth and length growth will affect the ratio of weight to length, a measure that is used commonly as a indicator of current malnutrition. An additional concern apparent from these analyses is that the predictors of failure in weight and length may be different.

Policy Implications

- It is important to pay more attention to how to prevent children's growth-stunting, given the strong associations between size and cognitive and behavioral function shown later in this report.

- Most growth stunting occurs prior to 18 months (Chapter Five), pointing to the need for *early* interventions. Nevertheless, length-stunting is still going on in the majority of preschoolers, and some are growing slowly in both weight and length. Thus, interventions may certainly improve growth during the 18 to 30 month period.

- Providing more energy or protein, in the form of foods similar to those already consumed by the majority of the children, is not likely to benefit preschooler's growth.

- In contrast, growth is likely to benefit from higher intakes of animal products, substituting for *tortillas*.

- Heavier maternal weight is associated with having a heavier, longer child at 30 months, but only if the child is eating enough animal products.

- Although higher socioeconomic status households produce larger children at 30 months, most of this effect was explained by the fact that mothers in such households weighed more, and fed more animal products to their children.

- Children with low intakes of animal products do not increase in weight and length at the same time. This means that weight and length growth measures are not interchangeable in monitoring, surveillance or research programs.

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Chapter Fifteen: Cognitive Development of the Preschoolers

Introduction

This chapter describes the relationships among growth-stunting, the quantity and quality of food consumed, and cognitive development at 30 months of age. Disentangling the effects of malnutrition from the effects of other factors that affect cognitive performance is made particularly difficult by the fact that cognitive development itself is an extraordinarily complex matter, involving multiple biological and social factors. Malnutrition may influence these factors in multiple ways. For example, in recent years, there has been increasing interest in the role of behavior as a factor in the delayed development typical of many malnourished children. Among the types of behavior that may be affected by marginal malnutrition are apathy, lack of attention, reduced exploratory behavior, and reduced interaction with the physical and social environment, all of which lead to reduced opportunities for learning. The subsequent chapter (Chapter Sixteen) will provide further data showing that malnutrition-related behavioral changes occur in these preschoolers.

Preceding chapters have illustrated several points that provide useful background to the analyses. First, size at 30 months is strongly determined by size at 18 months, especially in the case of length - in other words, a child who is small at 30 months was small at 18 months - and probably for long before that. In fact, endowment of the infant at birth is a strong predictor of subsequent growth. Second, dietary quality is important for the preschooler's growth and adequate micronutrient status.

Research Methods

Cognitive performance was measured at 18, 24 and 30 months using the Mental Scale Items of the Bayley Scale of Infant Development. As described in Chapter Three, the Bayley examination requires children to respond to a series of challenges that reflect their ability to process information and produce appropriate actions, such as identifying and manipulating objects. In other words, it samples a child's cognitive organization.

The results of the cognitive component of the Bayley examination are normally presented in the form of the Mental Development Index (MDI), which are standardized scores [1]. Because the scale measures developmental processes, the assessment of an individual child's performance can be expressed as the achievement of behaviors that are normatively achieved by children of a given age. Population distributions are thus the yardstick of measurement, in a manner that parallels the use of percentiles of weight-for-age or height-for-age to assess anthropometric performance.

However, while there is a theoretical, as well as an empirical basis to justify the use of an international standard for anthropometry, this is more problematic with respect to psychological development. In the Solís sample, the pattern of passes and fails on specific items did not directly parallel the developmental sequence of the U.S. children on whom the test was originally standardized. Some low-numbered ("easier") items were failed by a large percent of the children in the Solís communities, while some very difficult ones were passed by most of them. This pattern of responses suggests one should be very cautious about using the standard scores even for intra-group analysis.

Given the difficulties of interpreting the standard Mental Development Index, a cognitive performance score was constructed as a simple, additive scale of "total number of items passed." Because every child was exposed to all the items in the test battery, these scores can be used to compare or rank the performance of all children in the sample.

The preschoolers in these analyses consist of 78 children: 38 boys and 40 girls who were all weaned prior to 27 months of age. Food intake measures taken during the period 27-29 months of age reflect average intake in the 3 month period prior to cognitive testing at 30 months of age.

Table 15.1 shows the mean and range of cognitive scores at 30 months of age on the battery of test items included in the Bayley Mental Scale. While the range of scores for girls is slightly larger, there is no significant difference between the sexes.

Anthropometry, Diet and Cognitive Scores

Anthropometry and Cognitive Scores

Table 15.2 shows that there are strong associations between anthropometric measures at both 18 and 30 months and cognitive performance at 30 months. Larger body size at 18 months (both weight and length) is strongly associated with higher cognitive scores at 30 months. Similar associations are found with attained size at the time of the 30 month testing. However, there was no significant relationship between length at 18 months and cognitive performance at 18 months, and the correlation of weight with the cognitive score at this period is weaker ($r=0.27$, $p<0.03$). Thus, the relationship of prior size to the later cognitive performance of these children suggests the effects of chronic, earlier growth-stunting.

Table 15.1. Cognitive scores at 30 months.

	N	Mean	S.D.	Range
Males	38	43	(7.3)	31-54
Females	40	43	(6.0)	29-56

Intake Variables and Cognitive Scores

Children with higher mental scores at 30 months had a higher total energy intake during the preceding three months (Table 15.3). However, when energy intake is expressed per kg body weight it was unrelated to cognitive performance, showing the higher energy intakes of the higher scoring children to be due to larger size. The negative relationship between kcal/kg and mental scores is a reflection of the somewhat higher energy intake per kg of smaller children (Chapter Fourteen). The dietary quality measure (% kcal from animal sources) had a positive relationship with boys' and girls' mental scores, a higher proportion of energy from animal sources being associated with higher mental scores. As for growth (Chapter Fourteen), there is a tendency for preschoolers who consume better quality diets to perform better on cognitive exams.

To the extent that food intake is a primary factor influencing physical growth, it must also be regarded as an influence on the association between size and psychological performance. Therefore, an important question is whether dietary intake affects cognitive performance over and above its contribution to growth. Table 15.4 presents the results of a regression analysis in which both length and dietary quality are used as predictor variables. It can be seen that the effect of length remains significant even when dietary quality enters the model first and is allowed to explain as much of the variance in mental scores as possible (Type I). However, the effects of dietary quality are eliminated when both length and dietary quality enter the model simultaneously (Type III). This suggests that any effects of dietary quality are primarily through preschooler size. Using length alone, 22% of the variance in mental scores is explained.

Illness is one important factor with the potential to influence growth. It may also be hypothesized that illness influences cognitive development independently of intake-growth interactions by affecting the nature of child-caretaker relationships and the relationships of the child to his or her environment. However, there were no significant associations between a child's morbidity experience and cognitive development. As argued elsewhere (Chapter Fourteen), this may be due in part to difficulties in modeling subclinical morbidity, and to problems related to the morbidity protocols (Chapter Nine).

Table 15.2. Correlations between anthropometry at 18 and 30 months and cognitive scores at 30 months (N=70).

		Mental Score at 30 Months (N=70)					
		Total		Girls		Boys	
Age	Variable	r	p	r	p	r	p
18 months	Weight	.36	(.002)	.40	(.01)	.35	(.04)
	Weight Z	.39	(.0008)	.41	(.01)	.35	(.04)
	Length	.40	(.0007)	.54	(.0005)	.32	(.07)
	Length Z	.42	(.0003)	.51	(.01)	.29	(.09)
	Head Circ.	.23	(.05)	.23	(ns)	.35	(.04)
	Lower Arm Circ.	.32	(.007)	.32	(.05)	.34	(.05)
	Upper Arm Circ.	.35	(.003)	.30	(.07)	.41	(.02)
30 months	Weight	.35	(.002)	.44	(.006)	.34	(.05)
	Weight Z	.37	(.001)	.43	(.007)	.33	(.05)
	Length	.33	(.007)	.53	(.001)	.16	ns
	Length Z	.39	(.001)	.53	(.001)	.23	ns

Table 15.3: Associations between diet and mental score at 30 months.

	Mental Score at 30 Months					
	Total		Girls		Boys	
	r	p	r	p	r	p
Kcal	.36	(.002)	.40	(.01)	.35	(.04)
Kcal/kg	-.17	(ns)	-.12	(ns)	-.22	(ns)
% Animal kcal	.23	(.04)	.22	(ns)	.27	(ns)

Table 15.4: Multiple regression model for effects of length and dietary quality on cognitive score.

Independent Variable	Parameter estimate	p-value (type I)	p-value (type III)
% Animal kcal	.006	.03	.46
Length Z at 18 mo	2.320	.003	.003

R-SQUARE = 0.18 ROOT MSE = 6.33

Cognitive Performance and the Household Context

Simple correlations were used to determine which of the following maternal and household characteristics were statistically related to cognitive performance scores at 30 months of age: maternal age, birthplace, literacy, and household management as measured by the young child appearance score. The household level variables examined were: total household size, number of children under 12 years of age; family structure (nuclear vs. extended); type of marriage (patrilocal, matrilocal or neolocal) and socio-economic status.

Cognitive scores were not significantly related to mother's age, birthplace, or literacy. However, the cognitive performance score was strongly correlated (r=0.37, p=0.001) with children's physical appearance.

One household level variable, socio-economic status, has a significant relationship to preschooler cognitive scores (r=0.30, p=0.009). The number of household members, and household composition were not related to children's cognitive performance. Girls in matrilocal households have significantly higher scores than those in patrilocal or neolocal families. However, there are only 7 girls in this group and the relationship does not hold up for boys. Therefore, it is difficult to assess the meaning of this finding.

Based on the bivariate analyses, the socioeconomic status and child appearance measures were selected for use in multiple regression analyses to assess their independent and additive relationships to cognitive performance.

Table 15.5: Regression model for effects of socioeconomic status and dietary quality on cognitive scores.

Independent Variables	Parameter estimates	p value (type I)	p value (type III)
% Animal kcal	.001	.04	.17
Socioeconomic Status	.007	.36	.36

R-SQUARE = 0.06 ROOT MSE = 6.70

Table 15.6: Regression model for effects of socioeconomic status, dietary quality and length at 18 months on cognitive score.

Independent Variables	Parameter estimates	p value (type I)	p value (type III)
% Animal kcal	.004	.003	.20
Length Z at 18 mo	2.27	.0009	.007
Socioeconomic Status	.002	.15	.15

R-SQUARE = 0.18 ROOT MSE = 6.4

Multiple Regression Models Predicting Cognitive Performance

Models Including Socioeconomic Status

Table 15.5 shows a regression model that includes socio-economic status and dietary quality as predictors of mental performance. Although both variables are significantly related to cognitive performance in bivariate analyses, neither remains significant in the presence of the other. This is in keeping with the strong relationship between dietary quality and socio-economic status in these communities (Chapter Seven). However, when length at 18 months is added to the model (Table 15.6), it retains its predictive value. Again, this suggests a causal relationship between prior size and subsequent cognitive performance, which is independent of other factors that affect development.

Models Including Maternal Management

A regression model containing 18 month length and child's appearance score showed both variables to be highly significant and together explained 27% of variance in mental scores (not shown). The addition of dietary quality to the model explained no more of the variance (Table 15.7). Similarly, the addition of SES to child's appearance and 18 month length added little to the model (Table 15.8). Children's appearance scores and SES are not significantly correlated with each other ($r=0.18$, ns), although 18 month length is associated with both of these social measures (*child's appearance*: $r=0.34$, $p<0.005$; *SES*: $r=0.33$, $p<0.005$). Thus, child's appearance/maternal management is not simply a proxy for SES.

Conclusions

In this population, it is clear that smaller children do not perform as well in cognitive testing as do those who are larger. Moreover, those who are short at 18 months of age perform more poorly at 30 months, one year later, on tests that challenge their cognitive organization. Therefore, it appears that in the Solís Valley, as in many other parts of the world, those factors that lead to small size also lead to impaired cognitive development.

The lack of association between recent (last 3 months) energy intake and cognitive performance most likely reflects the general adequacy of energy intake in these children (Chapters Six and Fourteen). That is, even given a threshold below which energy intake affects cognitive development, the majority of the children in the sample are likely to be above this threshold. In contrast, current dietary quality (as measured by the proportion of energy from animal products) may play a role in current performance. This may reflect currently inadequate intakes of vitamins and minerals that affect cognitive performance. Or, current dietary quality may

Table 15.7: Regression model for effects of child's appearance, dietary quality and length at 18 months on cognitive scores.

Independent Variables	Parameter estimates	p value (type I)	p value (type III)
% Animal kcal	.003	.03	.71
Length Z at 18 mo	1.84	.002	.02
Child's Appearance	.043	.03	.03

R-SQUARE = 0.24   ROOT MSE = 6.2

Table 15.8: Regression model for effects of child's appearance, socioeconomic status and length at 18 months on cognitive scores.

Independent Variables	Parameter estimates	p value (type I)	p value (type III)
Length Z at 18 mo	1.83	.0003	.0184
Child's Appearance	.04	.0237	.0249
Socioeconomic Status	.003	.6699	.6081

R-SQUARE = 0.23   ROOT MSE = 6.1

be a continuation of the quality of the diet that the child (and the child's mother) has received since early infancy, and even pregnancy. This is particularly likely as mothers' and infants' intakes are tightly linked to the household food pattern (Chapter Seven), and the household food intake pattern is unlikely to change rapidly. For this reason it is impossible to conclude from these analyses whether it is current dietary quality, or growth-retardation caused by poor dietary quality in the past (Chapter Fourteen), that leads to delayed cognitive development. However, any relationship with current dietary quality disappears when 18 month length is taken into account. This argues for a stronger role for past growth than for current diet.

The CRSP design included measurements of variables reflecting the influence of social environmental factors on cognitive development. In this chapter, two indicators of the child's environment were considered because they were associated with the mental scores. These were the managerial activity of the child's primary caretaker, which in the Solís Valley is the mother, and secondly the socioeconomic status of the household in which the child spends most of his or her time. For this assessment we have selected several variables of mother characteristics and household characteristics as *indicators* of the complex "environmental" conditions that affect child development. The influence of the social environment, both material and behavioral, on the children's cognitive development is strongly confirmed by the zero-order correlations. When SES and child appearance are entered simultaneously, the maternal care-taking variable is much stronger than socioeconomic status. Mental development may be compromised by an interaction between child passivity and maternal time allocation in households where child care time is limited because the caretakers are pushed by economic necessity to long hours of work. In such a situation low intake in the child *interacts* with the behavioral consequences of poor economic resources, with each component contributing to and reinforcing a less than optimal outcome.

Pollitt has suggested that the interactive effects between nutrition and socioeconomic circumstances are more powerful than the main effects of nutrition, and that socioeconomic deprivation apparently potentiates the effects of early undernutrition [2]. The analyses presented in this chapter lend strong support to an interactive model of nutrition and development, as proposed by Pollitt and others. Social-environmental conditions of the household clearly affect development. The biological and behavioral experiences of the child, as reflected in growth, also affect development. The mechanism of these effects is probably synergistic. That is, child nutrition, health and activity (reflected in growth) have a synergistic relationship with social and social-relational conditions for risk of poor or delayed cognitive development.

Policy Implications

- Prevention of early growth stunting will have important positive effects on children's ability to acquire knowledge and skills in primary school, since there is clear evidence that early growth stunting affects cognitive development during a period in which basic skills necessary for later success in formal education are being acquired.

- Improving dietary intake of children in the post weaning period is likely to have positive effects on cognitive development, additional to effects associated with prevention of pre-weaning growth stunting.

- Empowering women with the resources to manage their households and child care responsibilities effectively will prevent delays in cognitive development associated with maternal management stress.

References

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Chapter Sixteen.
Preschooler Behavior: Small is Unhappy

Introduction

In intervention studies where nutrient supplements have been used, malnourished children exhibit alterations in activity patterns and social interaction compared to supplemented peers [1,2,3,4]. Deficits in these functions may limit their social-emotional and cognitive development [2]. Often such children are described anecdotally as apathetic and emotionally withdrawn, eliciting less response from adults and peers. However, there has been no previous attempt to describe the impacts of marginal malnutrition on the full range of daily activities and behaviors of preschoolers, particularly in a non-intervention setting.

The early growth faltering of Solís Valley children was described in Chapters Five and Fourteen. By 18 months of age, when the Solís preschoolers were recruited for study, most growth-faltering had already occurred. In this chapter we describe relationships between anthropometric measures, food intake, and the activity, behavior, emotions and social interaction of the Mexican preschoolers. Observational methods were used to assess these outcomes. This research protocol was designed and implemented by Dr. Kelley S. Scanlon during her doctoral research at the University of Connecticut. Eudwiges Tellez played a major role in data collection and coding. Dr. Alfonso Mata also assisted in supervising all aspects of the study, and Justina Contreras, Guadalupe Moreno and Silvia Urbina collected a major proportion of the data. Additional details of the methods and analyses are available elsewhere [5,6].

Measurement of Activities and Behaviors.

The 49 mother-preschooler pairs observed were from three of the study communities. They represented all mother-target preschooler pairs in the CRSP at the time the observations commenced. There was a 4% rate of refusal to participate. The analyses presented here are limited to 33 mother-preschooler pairs who were observed when the child was 24 to 31 months of age; for the other 16 pairs some observations were made when the children were younger or older.

An observation protocol was designed to quantify the activity patterns, behavioral characteristics, emotions and social interaction of the mother-preschooler pairs. Table 16.1 summarizes the visit schedule, types of observations, and categories of variables studied. At hourly intervals, from 0800 to 1800, one day per month for 8 mo, an observer arrived at the child's home and made

Table 16.1: Visit schedule.

Time		Observation Variable Categories
Each hour from 0800 to 1800, one day per month, for 13 months	Spot observation on arrival	Location Body position Attributes of body position Activity Attributes of activity Affect Interaction Presence of individuals Attributes of interaction
	10-minute observation after arrival	Location Body position Attributes of body position Affect Interaction Presence of individuals Attributes of interaction

a *spot*, or *snap-shot*, observation of what was occurring at that moment. This was followed by 10 min of continuous observation. In part the three different types of observations were collected for comparison, in order to establish the best methodology for future research. In addition, it was recognized that the length of time the observer was present might affect different behaviors in different ways. For example, at the moment of arrival for a spot visit to the home an observer may interrupt certain behaviors (such as interactions with others) that will be resumed during their subsequent 10-min presence in the house. On the other hand, the presence of the observer in the home may alter, for example, the child's activity or emotions. The 8 days of observation (88 spot and 88 hourly ten-minute observations) per participant included at least one on each day of the week except Sunday.

Inter-observer reliability was calculated for the three observers for 10% of the observations. All observations were coded by both the investigator and coder during the initial months of coding, after which 10 % were coded by both. Greater than 95% inter-observer and inter-coder reliability was maintained throughout the study.

All behaviors that occurred were noted during both spot and 10-min observations. Only observations on the preschoolers are reported here.

For statistical analysis the detailed categories of children's behaviors were collapsed into sets of variables based on major classifications of behavior, and those that occurred rarely were deleted. For example, 47 different types of children's activities were recorded in the field but these were grouped into 10 main *activity* variables (Table 16.2) for statistical analysis. Table 16.2 provides a list of the analysis variables and the categories of behavior to which they correspond.

Following the development of the coding categories, the percent of occasions during which each child was observed in each behavior was calculated for both spot and 10-min observations. In addition, the principal activity of the 10-min observation was defined as that which occupied most time during the observation.

Only one behavior was recorded per spot observation. The percent of occasions that each behavioral variable was observed during spot observations was calculated for each individual. Similarly, the percent of occasions that the principal activity was observed was calculated as: (# of occasions the activity was the principal one of a 10-min observation / # of 10-min observations) X 100.

A slightly different approach was used for the 10-min observations, because several different behaviors might have been recorded and the same behavior could have been repeated several times. Therefore percent observation of a specific behavior during 10-min observations was calculated for each child as: (# of occasions the behavior was observed at least once / # of 10-min observations) X 100. Even if a specific behavior was observed several times during a 10-min observation, it was still counted only once. However, if several *different* behaviors were observed during the 10 minutes, each received a score of one in order to capture the spectrum of behaviors observed. Thus the results for spot and 10-min observations cannot be compared directly. However the results of the spot and principal activity of the 10-min observations can be compared, since they were calculated by similar methods.

Spearman and Pearson correlations tested the significance of associations between behavior, and anthropometry and food intake. The independent samples t-test and chi-square test of independence were performed to examine differences between children who were identified as marginally malnourished and those who were not. An approximate t-test was used when an F-max test indicated non-homogeneity of variance ($p<0.05$).

Behavior, Anthropometry, and Food Intake

Table 16.3 shows the percent of occasions on which the preschoolers were observed in specific activities. As expected for reasons described above, there were some differences between the results for spot and 10-min observations. The children had *no activity* during approximately 25% of the spot and principal activity observations, and nearly 40% of the 10-min observations. This phrase describes the child who was *doing nothing*, not participating in any activity or interacting with another individual. It differs from *resting*, which includes lying down for a nap. The other most frequently observed activities were quiet play and eating. Table 16.4 presents mean values

Table 16.2: Main categories and variables studied.

Category	Variables
Activity	No Activity; Follows Adult; Verbal Interaction; Active Play; Quiet Play; Locomotion; Eating; Resting; Sleeping; Being Changed/cleaned
Attributes of Activity	Shows Lack of Interest; Shows Interest; Shows Imagination; Shows Curiosity; Disobedient; Obedient
Affect	Neutral Affect; Cries; Smiles, Laughs; Expresses Anger; Expresses Excitement
Interaction	Interaction w/Any Other Individual; Interaction w/A Specific Individual, i.e. Mother, Father, Sibling, Other Relative, etc.
Absence of Interaction	No Interaction When Child Was Alone.; No Interaction When Others (listed above) Were Present.
Attributes of Interaction	Unsociable; Sociable, Friendly; Requests Food, Objects; Obeys Orders; Seeks Affection; Holds Child's Hand; Physical Contact; Aggressive; Request is Met; Receives Attention; Being Carried, Held; Being Talked to; Aggressive; Request is Met; Receives Attention; Being Carried, Held; Being Talked to

for anthropometry between 24 and 31 months of age. The low median Z-scores for both weight- and length-for-age indicate growth-stunting, whereas the normal median weight-for-length Z-score shows that wasting was not common.

Based on the triceps skinfold thicknesses the children were around the 25th percentile of fatness on average. Individuals ranged from below the 5th to above the 95th percentiles for fatness and arm muscle circumference, indicating the wide range of body composition among children. There were at least 8 days of post-weaning dietary records per individual, and 14 on average.

Table 16.3: Percent occasions observed in selected activities (N=33).

Activity	Spot	10-Minute	Principal
No Activity	25.6	38.9	25.6
Quiet Play	21.2	27.1	19.8
Eating	11.2	12.2	9.8
Sleeping	10.6	1.2	9.4
Follows Adult	7.4	4.9	6.5
Active Play	6.1	10.2	6.3
Locomotion	5.4	11.2	3.5
Verbal Interaction	4.6	10.2	2.5
Being Changed/cleaned	2.1	4.5	2.1
Resting	2.0	3.4	1.8

Table 16.4: Description of anthropometry (N=33).

	Mean	Median	Range
Size			
Weight/age Z-score		-1.1	-2.2 - 1.3
Length/age Z-score		-1.6	-3.0 - 0.0
Weight/length Z-score		-0.3	-1.4 - 1.5
Body/Composition			
Mid-upper Arm Circ.(cm)	15.2 ± 0.87	15.1	14 - 18
Triceps Skinfold (mm)	8.1 ± 1.30	8.2	6 - 11
Arm Muscle Circ. (cm)	12.7 ± 0.72	12.6	12 - 15

Table 16.5: Description of diets (N=33).

	Energy (kcal/d)		Protein (g/d)	
	Mean	Range	Mean	Range
Intake (kcal/d)				
Total	1168 ± 313	664 - 1965	36 ± 9	21 - 53
Animal	144 ± 113	3 - 487	10 ± 7	0 - 34
Plant	1023 ± 330	415 - 1869	25 ± 9	8 - 45
% Animal	13 ± 11	0 - 49	28 ± 18	1 - 78
% Plant	87 ± 11	51 - 100	72 ± 18	22 - 99

As for the larger group of preschoolers (Chapter Six) average energy and protein consumption (Table 16.5) was close to the recommended levels of 102 kcal/kg (girls) and 104 (boys), and approximately 2.7 g protein/kg, for children of this age. However, there was a wide variation in intake and only 13% of the energy and 28% of the protein was from animal sources, with some children consuming no animal products.

Relationships Between the Children's Size and Behavior.

To interpret patterns between behavior, and anthropometry and diet, the behaviors have been grouped into *positive* or *negative* categories. Negative behaviors were defined as those that reflect apathy, or a less expressive, fussy child (e.g. *neutral affect*, *no interaction*, and *cries*). Positive behaviors are characteristics of a child who is more active, emotional, interactive, and involved with his or her environment (i.e. *interaction*, *play*, *expresses excitement or anger*). While some behaviors (for example *being changed or cleaned* and *request is met*) are actually responses of the caretaker, they are included here on the assumption that they indicate the child was demanding more attention. For reasons discussed above the correlations between variables may be different for spot, 10-min and principal activity observations.

As can be seen in Table 16.6, the overall pattern was that bigger children (higher weight- and length-for-age, and weight-for-length), tend to show more positive and less negative behaviors. Specifically, heavier children were less likely to be inactive, passively following an adult, showing neutral affect, or crying. They requested/demanded food or objects on fewer occasions compared to lighter children. On the other hand they interacted verbally and moved about on more occasions, engaged in more imaginative behavior, and were more often observed smiling and laughing and interacting with other children.

The pattern of correlations between length-for-age and behavior was similar to that observed for weight-for-age. Taller children were less likely to be observed in the more inactive or passive

Table 16.6: Significant associations between behavior and size (N=33).

	Weight-for-Age			Length-for-Age			Weight-for-Length		
Behavior	**Spot**	**10-Min.**	**Princ.**	**Spot**	**10-Min.**	**Princ.**	**Spot**	**10-Min.**	**Princ.**
Negative									
No Activity	-.33*	-.30*	-.32*	-.30*	-.18	-.29*	-.16-	.29	-.17
Follows Adult	-.42†	-.22	-.22	-.30*	-.15	-.11	-.41†	-.32*	-.28
No Affect		-.52‡				-.51‡	-.39†		
Cries	-.54§	-.42†	-.19	-.36†		-.49‡	-.41†		
No Interaction	-.09	-.27	-.26	-.29*	-.08	-.05			
W/father No Interx	-.01	-.19		-.20	-.32*		-.14	-.31*	
W/child, No Interx	-.16	-.17		-.30*	-.28		.09	.11	
Request Food/object		-.43‡			.02			-.59§	
Positive									
Verbal Interaction	.34†	.15	.15	.37†	.05	.15	.23	-.11	.07
Locomotion	.50‡	.13	.13	.37†	.01	-.00	.51‡	-.02	.03
Shows Imagination	.21	.35†		.22	.26		.05	.20	
Smiles/laughs	.13	.33*		.08	.28		.01	.23	
Interacts	.16	.25		.24	.34†		.01	-.0	
Interacts w/Mother	.19	.02		.29*	.18		-.00	-.18	
Interacts w/Father	-.09	-.18		-.14	-.21		-.06	-.34†	
Interacts w/Child	.29*	.31*		.22	.11		.18	.24	

* $p<0.10$ † $p<0.05$ ‡ $p<0.01$ § $p<0.001$

behaviors, and more likely to be moving about or interacting with others including their mother. They showed less failure to interact with their father.

Weight-for-length predicted children's behavior in a similar way. Those heavier for their length were less frequently observed with neutral affect, crying, following an adult or demanding food or an object. They were more likely to be moving about, although they interacted with their father less often. Body composition and growth rate were similar to body size in their relationships to behavior. In general, children with more estimated body fat or lean body mass, and those who were growing faster, were less likely to have an absence of activity, emotions, or interaction. For example, for the 10-min observations the rate of weight gain was positively associated with active play ($r=0.35$, $p<0.05$) and interacting with children ($r=0.57$, $p<0.05$). Children who grew faster in length were less often observed in *no activity* ($r=-0.37$, $p<0.05$), with neutral affect ($r=-0.59$, $p<0.001$), or crying ($r=-0.37$, $p<0.05$).

Relationships Between the Children's Diet and Behavior.

Children consuming more energy were *more* likely to exhibit negative behaviors including neutral affect, crying, and to be with their mother and other children without interacting with them (Table 16.7). They played more, expressed anger on more occasions, were less sociable, and were less likely to hold hands with other children. Their caretakers answered their demands more often. The pattern of correlations between energy from plant sources and behavior (not shown) was similar to that for total energy, which is expected because of the strong correlation between total energy and energy from plant sources.

In contrast (Table 16.7), children who consumed more energy from animal sources were less likely to show negative behaviors or neutral affect. They engaged in more verbal and nonverbal interaction with family and peers, and were changed or cleaned more often.

Correlations between behavior variables and protein intake were almost identical to those for energy intake because of the strong correlation between energy and protein intake (total, $r=0.87$, $p<0.0001$; animal energy vs animal protein, $r=0.98$, $p<0.0001$; plant energy vs plant protein, $r=0.92$, $p<0.0001$). In general, children consuming more total protein or protein from plant sources were less active and interactive, whereas those consuming more animal protein were more active and interactive.

Comparison of Stunted and Normal Children

For these analyses, children with a mean length- or weight-for-age Z-score less than -1.5, or approximately the 7th percentile, were identified as marginally malnourished. (Using -1.65 Z, equivalent to the 5th percentile, produced virtually identical results as only one child fell between - 1.5 and -1.65 Z). A lower cut-off point, such as the frequently-used -2 Z suggested as denoting

Table 16.7: Significant associations between behavior and energy intake (N=33).

Behavior	Total Energy Intake			Energy from Animal Sources		
	Spot	10-Min.	Princ.	Spot	10-Min.	Princ.
Negative						
Eating	.20	.25	.27	-.20	-.35*	-.32†
No Affect		.32†			-.30†	
Cries	.29	.48‡		-.21	-.26	
W/Mother, No Interx	.30†	.20		.10	-.23	
W/Child, No Interx	.32†	.40*		.04	.09	
Positive						
Verbal Interx	-.09	.23	-.12	.43*	.34†	.40*
Active Play	.22	.38*	.27	.04	.20	.13
Being Changed	-.14	.09	-.19	.54‡	.10	.50‡
Express Excitement		.12				-.34†
Express Anger		.30†			-.10	
Interx w/Children	.15	.05		.31*	.10	
Sociable, Friendly		-.38*			.06	
Holds Child's Hand	-.36*	-.01		.30†	.18	
Request is Met		.38*			-.32†	
Being Talked to	-.12	-.13		.28	.66§	

*$p<0.05$ † $p<0.10$ ‡$p<0.01$ §$p<0.001$

marginal malnutrition, did not show significant differences in behaviors between groups suggesting that adverse effects occur with a lesser degree of stunting than is estimated with a -2 Z cut-off. No children had a weight-for-length Z-score less than -1.5 as they were not wasted.

Heavier children (> 1.5 Z for weight) were taller (-1.36 Z vs -2.18 Z, $p<0.001$), had a larger weight-for-height (0.01 Z vs -0.68 Z, $p<0.001$) and mid-upper arm circumference (12.9 vs 12.2, $p<0.001$) but did not differ in triceps skinfold thickness (Table 16.8). Taller children were heavier (-0.44 Z vs -1.42 Z, $p<0.001$), had a significantly greater arm muscle circumference (13.0 vs 12.4 cm, $p<0.03$) and grew faster in length (10.2 vs 8.2 cm/y, $p<0.03$), but did not differ in fatness or weight-for-height from those in the shorter category. Table 16.8 shows significant differences between *weight* and *length* groups with respect to the children's behavior. In general, children in the heavier, or taller groups were less likely to be observed in negative behaviors, and more likely to be behaving positively.

Table 16.8: Characteristics of heavier, taller children.

Anthropometry
- ↑ Weight-for-length (wt grp)
- ↑ Mid-upper arm circumference
- ↑ Arm muscle circumference

Diet (18-31 months)
- ↑ Total and % energy from animal
- ↑ Total and % animal protein

- ↓ % Energy from plants (18-24 months)
- ↓ % Plant protein (18-24 months)

Morbidity
- ↑ Reported illness (length)
- ↑ Reported diarrhea (length)

Social
- ↓ SES (weight)
- ↓ Father migration
- ↑ Home construction (length)
- ↑ Home appearance (length)
- ↑ Literacy of mother (length)

Lighter children, with a weight-for-age Z-score < -1.5, compared to heavier peers showed an absence of activity on about two thirds as many occasions, were following an adult or crying during half as many observations, and were more likely to interact with other individuals who were present. They also requested food or objects less often and were less sociable (data not shown).

On the other hand, heavier children interacted verbally and were observed playing during 50 to 80% more of the observation periods. They walked and ran (*locomotion*) 3 to 4 times more often, and were more imaginative and interactive with others.

Associations between length-for-age group and behavior showed a similar pattern (Table 16.8). Taller children were less likely to be inactive or not interacting, and they participated in twice as much verbal, and more non-verbal, interaction.

Table 16.9: Significant differences between weight and length groups with respect to percent of occasions observed in specific behaviors (N=33).

	Weight Groups			Length Groups		
Behavior	**>-1.5 Z (n=23)**	**<-1.5 Z (n=10)**		**>-1.5 Z (n=14)**	**<-1.5 Z (n=19)**	
Negative	%	%	t	%	%	t
No Activity (spot)	22.9	31.3	2.95*	21.7	28.5	2.46†
Follows Adult (spot)	6.1	10.0	2.66*			
Cries (spot)	2.4	5.8	4.26‡			
No Interaction (10-min.)	65.4	78.9	1.93§			
W/Father, No Interact (10-min.)				4.3	9.8	2.85*
W/Mother, No Interact. (spot)				44.2	52.3	1.66§
Positive						
Verbal Interaction (spot)	5.2	3.0	-1.81§	6.1	3.4	-2.46†
Active Play (10-min.)	11.8	6.6	-2.10†			
Quiet Play (10-min.)	29.9	20.5	-2.33†	21.5	17.5	-1.74 §
Locomotion (spot)	6.7	2.3	-3.81‡	6.8	4.3	-1.99§
Shows Imagination (10-min.)	5.3	1.4	-3.77[11]‡			
Interacts (10-min.)	77.1	62.0	-2.40†	81.5	65.9	-2.73*
Interacts w/Mother (spot)				10.0	7.1	3.55§

* $p<0.01$ † $p<0.05$ ‡ $p<0.001$ § $p<0.10$

[11] Approximate t assuming that variances are unequal.

Implications of Being "Small and Unhappy".

In these Mexican preschoolers, growth-stunting and poor dietary quality are associated with functional impairment. Specifically, the behaviors most consistently and strongly indicative of growth-stunting and a low intake of animal products are: less activity (more *doing nothing*), more passive following of an adult, less affect, more crying, and less positive interaction with others. Growth-stunting, but not food intake, was also associated with less locomotion. In contrast, larger, faster-growing children consume more animal products, are more active and interactive, and more involved with their environment. Children who suffer growth retardation as a result of malnutrition show behavioral patterns in early childhood that may well affect the quality of their life and their ability to function in society. These findings refute the "Small, but healthy" hypothesis of authors such as Seckler [7,8], and have important implications for public health and nutrition policy.

In this population children's growth, school performance and cognitive development are strongly predicted by the proportion of dietary energy and protein that is consumed in the form of animal products, but not by total energy or protein intake. As discussed in Chapter Six those children who rely heavily on *tortillas* also consume few or no animal products, and their dietary pattern is associated with poor bioavailability of nutrients such as zinc and iron. Poor dietary quality may affect activity directly, or act through an indirect effect of increased morbidity, which, in turn, reduces activity. The latter is less likely in view of the relatively low level of morbidity in Solís children as reported by their mothers. Also, there were no significant differences between the two weight or length groups with respect to the incidence of morbidity. Early dietary deficits may limit the children's capacity to interact with people and objects in their environment, thus affecting their social-emotional development and later behavior.

These results also underscore the importance of developing and utilizing functional measures of nutritional status that are sensitive to chronic or early malnutrition. The methodology of this study was time-consuming, involved repeated visits to the households, and required intensive training of the observers and coders. However, we have identified a "short-list" of behaviors that are most sensitive to growth-stunting and inadequate dietary intake, and these alone may be adequate for further studies of these relationships. On-going analyses are expected to demonstrate that fewer observations are necessary to capture these behavioral changes.

Finally, negative behavior patterns were identifiable below a weight- or length-for-age Z-score of -1.5. Using a Z-score cut-off of -1.65, equivalent to the 5th percentile, produced an almost identical result. It is important to note that this comparison was made against the behavior of the larger children, almost none of whom were actually well-nourished (Z-score of zero or above). Further work is needed in other populations to define anthropometric cut-offs that are likely to predict behavioral consequences of malnutrition.

Policy Implications

Growth stunting and poor dietary quality are associated with behavioral changes in preschoolers. Specifically, the behavioral changes are more apathy (*doing nothing*), more passive following of an adult, less affect, more crying, and less positive interaction with others. The implications of such behavioral differences are:

- Based on the present evidence it must now be recognized that marginal malnutrition not only has negative associations with children's growth and mental function, but has adverse effects on their emotions and behavior, quality of life and ability to function in society. These are serious short-term consequences for children and their households, and may handicap local and national development potential.

- The apathy and passivity must surely affect the children's interactions with other persons and their environment, leading to further delays in social-emotional, perhaps mental, development.

- From the large number of behaviors observed in this research, a "short list" has been identified that may be modified as a practical assessment tool in surveillance and intervention studies.

- Behavioral changes were seen below a weight or length Z-score of -1.5. If our results are replicated in other environments this may change the commonly-accepted -2 Z definition of malnutrition.

- It is important to determine the extent to which the behavioral impairment can be reversed by improving dietary quality, by nutrient supplements, and/or by a stimulating environment.

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Chapter Seventeen: Behavior and Cognitive Performance of the School-Aged Child

Introduction

The early school years are an important time for the acquisition of skills and knowledge that determine in many respects the economic and social potential of an individual. However, the acquisition of these skills requires exposure to educational systems and the intellectual and social skills to take advantage of them. Malnutrition may be a major barrier to the education of Third World children. Anecdotal evidence has long linked behavioral and cognitive effects to severe malnutrition. In recent years, investigators have shown that severe malnutrition (marasmus and kwashiorkor) in early childhood is indeed associated with performance deficits that do not appear to be overcome later in life [1,2,3]. Severe malnutrition in early life has also been found to be associated with important alterations in the behavior of school-aged children, including apathy, poor attention, reduced social responsiveness, and difficulty in regulating state and behavior.

Given the higher prevalence of mild-to-moderate malnutrition in less developed countries, the effects of this type of malnutrition on behavior and cognitive function have the potential to be a far greater social problem than the more dramatic effects of marasmus and kwashiorkor. Unfortunately, the relationship of mild-to-moderate malnutrition to the behavior and cognition of children is less than clear [4]. This is due in part to the close associations between poverty, malnutrition, and psychological performance and behavior.

The Measurement of Cognitive Performance and Behavior

The analyses presented in this chapter are taken from the analyses performed by Dr. Se-Young Oh [5,6,7]. The sample employed in the cognitive analyses consists of 107 children in the school-age sample (53 boys and 54 girls), who had complete records for cognitive testing, anthropometry, household socio-economic and demographic data and at least 8 days of dietary measures. The behavioral analyses are for 83 children (42 boys and 41 girls) who had complete records for behavioral data. These children were approximately nine years old during the study period (for the cognitive sample the mean age was 8.8 ± 0.5 years during the study, with a range of 7.5-10.2 years). The distribution of ages was similar for the behavioral sample.

The Research Instruments

Cognitive Performance

The cognitive performance of the children was measured with a modified version of the WISC-R instrument (See Chapter Three). Composite scores of cognitive performance were constructed based on the recommended classification of the WISC-R tests into a Verbal and a Performance scale. A composite *Verbal Scale* score was calculated as the mean of percent correct answers on the Digits Forward, Digits Backward, Vocabulary, and Arithmetic tests. The *Performance Scale* score is the mean of the percent correct responses on the Raven's Matrices, Block Design and Maze tests. The correlation between the two scales was statistically significant ($r=0.53$ for boys and $r=0.58$ for girls at $p<0.001$).

Teacher's Ratings

The behavioral characteristics of the school-aged children were assessed by teachers using modified versions of two instruments (Chapter Three): the Behavioral Checklist (BPC)[8], and the Affect Expression Rating Scale (AERS-C)[9]. The psychologist in charge of the field site visited the school teachers of all children in the study, and explained the purpose of the rating form and the meaning each item. For each behavioral item, the teacher was asked to rate the child with respect to its applicability to that child.

The Behavioral Problem Checklist

The original BPC consists of 55 items in 4 behavioral categories: *conduct disorder*, *personality disorder*, *immaturity*, and *social delinquency*. The adapted checklist used in the Mexico CRSP included 50 items, mainly from the *conduct disorder* and *personality disorder* categories. Of the 50 items in the modified BPC, 24 items were used to create two summary measures of behavior: *acting-out* and *withdrawn*. Construction of these variables was based on principal components analyses of items that were checked for 20% or more of children. A two factor solution was found to be both optimal and theoretically interpretable. Items loading strongly on the two factors were used in the creation of the two indices. Cronbach's alpha and inter-scale correlations were used to assess the reliability of the two scales.

The Affect Expression Rating Scale (AERS-C)

The Mexico CRSP employed a modified version of the AERS-C [9]. The original AERS-C is composed of 37 items: 13 measure characteristics of *introversion*, 15 measure aspects of *extroversion*, and 9 *'questionable'* items. The Mexico CRSP checklist contained 25 items: 9 from *introversion*, 11 from *extroversion*, and 5 from the *questionable* category.

Two summary measures based on the AERS-C items were constructed in a manner similar to that used for the BPC items. All 25 items were included in principal components analyses. A two factor solution was selected on theoretical grounds. Factor one consisted of 6 items from the *extroversion* category, and 3 items from the *questionable* group. The factor was termed *Social Competence*. Factor two was labelled *Introversion*, containing 5 items from the AERS-C *introversion* category. As with the BPC scales, Cronbach's alpha was used to assess scale reliability.

The Distribution of Cognitive and Behavioral Scores

The mean *cognitive performance score* for boys was 35.2 (SD=11.2, range 16.8-65.5), while for girls it was 31.1 (SD=12; range 6.5-64.0). The *verbal score* for boys averaged 41.0 (SD=8.7, range (17.9-60.5) and for girls the average was 39.6 (SD=10.5, range 5.3-58.3). The range of values for these two measures is very wide, suggesting large differences in the ability of children to cope with the challenge of taking the tests.

Table 17.1 presents the descriptive statistics for the behavioral scales. The boys had marginally higher scores on *acting-out* than did girls (p=0.08). However, there were no significant sex differences in the other behavioral variables.

The Associations Among the Cognitive and Behavioral Variables

Children with higher cognitive performance scores tended to be more *socially competent* ($r=0.30$, $p<0.05$) and less *introverted* ($r=-0.42$, $p<0.05$). However, *acting out* and *withdrawn* showed no relationship to cognitive performance.

The Relationship of Anthropometry to Children's Psychology

Construction of Fatness and Size Variables

The measurement of children's anthropometry is discussed in detail in Chapter Three. For the analyses presented here, principal components analysis of anthropometric variables was used as a data reduction technique. Two factors emerged clearly. Factor 1, which contains triceps skinfold, upper-arm circumference and weight-for-height, can be given the label *fatness*. The variables weight-for-age, height-for-age, and head circumference load on Factor 2 which we term *size*.

Table 17.1: Descriptive statistics for the behavioral scales.

	BOYS			GIRLS			DIFFERENCE
	Mean	SD	Range	Mean	SD	Range	p-value
Acting-Out†	4.7	3.4	0-12	3.7	3.8	0-12	<.08
Withdrawn†	4.1	3.4	0-12	5.0	2.9	0-11	ns
Social Competence‡	24.3	7.1	12-40	23.3	6.3	11-42	ns
Introverted‡	14.8	5.7	6-29	14.8	4.1	8-24	ns

† n=41 for girls and n=42 for boys
‡ n=38 for boys and n=38 for girls

Table 17.2: Relationships of cognitive scores to food intake and anthropometry: bivariate and partial (SES controlled) correlations.

	BOYS (N=53)				GIRLS (N=54)			
	Performance		Verbal		Performance		Verbal	
	Bi.	Part	Bi	Part	Bi	Part	Bi	Part
Size	0.35†	0.26‡	0.36†	0.31†	0.30†	0.15	0.44*	0.27‡
Fatness	0.16	0.02	0.16	0.07	0.16	0.06	0.18	0.03
Energy	-0.03	0.06	0.04	0.16	-0.01	0.04	-0.25	-0.23
Diet Quality	0.48*	0.45*	0.36*	0.22	0.40*	0.19	0.40*	0.07
% Animal Energy	0.45*	0.34†	0.34†	0.20	0.27†	0.05	0.36*	0.06
% Tortilla Energy	-0.59*	-0.50*	-0.35*	-0.23	-0.34†	-0.13	-0.35†	-0.04

* p <0.01, † p <0.05, ‡ p <0.10

Size and Fatness in Relationship to Cognition and Behavior

Larger *size* was associated with better cognitive performance and verbal ability in both girls and boys (Table 17.2). Controlling for the effects of socioeconomic status weakens the correlations for both boys and girls, the reduction in the association being largest for the girls. In the case of the behavioral variables (Table 17.3), larger *size* was associated with boys who were less *withdrawn* ($r=-0.29$, $p<0.10$) and *introverted* ($r=-0.33$, $p<0.05$), and were somewhat more *socially competent* ($r=0.26$, ns). In girls, no such relationships were seen with the exception of larger girls tending to be rated as less *introverted* ($r=-0.31$, $p<0.10$). Controlling for socioeconomic status had little effect on the relationships for boys, but substantially lowered the association between *introversion* and *size* for girls.

Fatness, in contrast to *size*, was a poor predictor of variation in the cognitive variables for boys and girls. *Fatness* was also unrelated to the behavioral variables in girls, while fatter boys tended to be more *socially competent* and less *introverted*. Controlling for socioeconomic status, the associations of *fatness* with *social competence* and *introversion* in boys are essentially unaffected.

The Relationship of Diet to Children's Psychology

Construction of Dietary Quality Variables

For the analyses presented here a principal components analysis of the dietary data was conducted to obtain factor score values for the individual children. After plotting the initial eigenvalues, a one factor model appeared to be the most appropriate. The factor reflected differences in the quality of the children's diets; children who consumed a smaller proportion of energy from *tortillas* consumed more dairy foods (0.78), other vegetables (0.78), fruit (0.65) and meat (0.47). Thus, the dietary pattern for this group of schoolers is essentially identical to that discussed in Chapter Six.

The Effects of Dietary Energy and Quality

In both boys and girls, better cognitive and verbal performance were associated with better *dietary quality*, a higher proportion of energy from animal products, and less reliance on *tortillas* for dietary energy. Energy intake showed little relationship to either cognitive performance or verbal scores (see Table 17.2) with one exception: girls with higher energy intakes tended to have lower verbal scores. Higher energy intakes are a sign of more dependence on *tortillas* in these communities (Chapter Six).

Controlling for the effects of socioeconomic status (SES), there were clear sex differences in the pattern of relationships among nutritional variables, socio-economic status, and cognitive performance. For boys, the significant bivariate association of dietary quality with cognitive

Table 17.3. Relationships of acting-out and withdrawn scores to food intake and anthropometry: bivariate and partial (SES controlled) correlations.

	BOYS (N=53)				GIRLS (N=54)			
	Acting-Out		Withdrawn		Acting-Out		Withdrawn	
	Bi.	Part	Bi	Part	Bi	Part	Bi	Part
Size	-0.19	-0.21	-0.29*	-0.26	-0.04	-0.07	-0.08	-0.03
Fatness	-0.16	-0.18	-0.22	-0.18	-0.00	-0.02	0.07	0.12
Energy	0.04	0.07	0.17	0.11	-0.07	-0.06	0.01	-0.03
Diet Quality	0.05	-0.02	-0.12	0.09	0.14	0.13	-0.08	0.00
% Animal Energy	0.08	0.03	-0.14	0.05	0.33†	0.36†	0.06	0.16
% Tortilla Energy	-0.00	0.05	0.12	-0.05	-0.35†	-0.27	-0.15	-0.11

* $p < 0.01$, † $p < 0.05$, ‡ $p < 0.10$

Table 17.4. Relationships of social competence and introverted scores to food intake and anthropometry: bivariate and partial (SES controlled) correlations.

	BOYS (N=53)				GIRLS (N=54)			
	Social Competence		Introverted		Social Competence		Introverted	
	Bi.	Part	Bi	Part	Bi	Part	Bi	Part
Size	0.27	0.26	-0.33†	-0.31*	-0.01	-0.11	-0.31*	-0.19
Fatness	0.40†	0.42†	-0.35†	-0.39†	-0.08	-0.15	0.09	0.22
Energy	-0.19	-0.09	0.11	-0.01	-0.48‡	-0.44	-0.23	0.12
Diet Quality	0.33*	0.14	-0.25	0.00	0.39†	0.31*	-0.18	0.10
% Animal Energy	0.38†	0.23	-0.30*	-0.10	0.29*	0.20	-0.13	0.10
% Tortilla Energy	-0.40†	-0.31*	-0.28*	0.10	-0.35†	-0.27	-0.15	-0.11

* $p < 0.10$, † $p < 0.05$, ‡ $p < 0.01$

performance remained significant in the partial correlations. For girls, however, diet was not significantly correlated with performance when SES was controlled.

As with the cognitive variables, the behavioral variables are associated with the dietary quality measures (Tables 17.3 and 17.4). Boys who ate proportionately more animal products and less tortillas were rated by their teachers as more *socially competent* and less *introverted*. Total energy intake showed little relationship to the behavior of boys. Among girls, better diet quality was associated with better *social competence* and more *acting-out*. In contrast with the boys, higher energy intakes (more dependence on *tortillas)* were moderately associated with less *social competence* in girls ($r=-0.48$, $p<0.01$).

When the effects of SES were statistically controlled, the associations of diet with behavior were weakened for both boys and girls. However, higher *social competence* among boys remained associated with more animal products ($r=0.23$, $p<0.10$) and less *tortilla* consumption ($r=-.31$, $p<0.10$). For girls, the association between higher energy intake and lower social competence remained, and better diet quality continued to be associated with higher social competence ($r=0.31$, $p<0.10$).

The Effects of Schooling

The Distribution of School Grades

School grade for children was taken from school records. Although the standard deviation of age was small, the range in school grade was from 1st to 4th grade, with about 30% of children in Grade 1, and 30% in Grade 2; the remaining 40% were mainly in Grade 3, with a very small proportion in Grade 4. It should be noted that a criterion for inclusion in this study was school enrollment. Thus, the sample does not include the very small minority of children who had not enrolled in school by the legally mandated age. Enrollment, however, should not be construed as synonymous with attendance. A sporadic attendance record may be one of the factors that accounts for the wider range of grades among children relative to their narrower age range. There were no significant age differences between the first and the second graders or between children in the second and third grades.

School Grade, Cognitive Performance, and Behavior

As might be expected, performance on the cognitive test battery was significantly associated with school grade. For both girls and boys, higher grade was strongly associated with higher cognitive (boys: $r=0.51$, $p<0.001$; girls: $r=0.51$, $p<0.001$) and verbal (boys: $r=0.68$, $p<0.001$; girls: $r=0.72$, $p<0.001$) performance. The correlations remain highly significant when the effects of SES are controlled as indicated by the partial correlations. For boys, the partial correlations are 0.38 ($p<0.01$) for the Performance Scale and 0.63 ($p<0.01$) for the

Verbal Scale. For girls, the partial correlations are 0.41 ($p<0.01$) for the Performance Scale and 0.67 ($p<0.001$) for the Verbal Scale).

Higher school grade was also associated with lower *introversion* in boys ($r=-0.29$, $p<0.10$), and higher *social competence* in girls ($r=0.35$, $p<0.05$).

Diet, Size, and School Grade

Analyses showed the third and fourth graders to consume more animal products, fruits, and fewer *tortillas* than first and second graders (Table 17.5). First graders were more stunted in weight and height than children in higher grades. Third graders also had larger arm circumferences and weight gains during the year. Children in lower grades tended to be from lower SES households, and their parents performed less well in cognitive testing.

The Effects of the Social Environment

As described in Chapter Three, the Mexico CRSP collected information on several characteristics of the parents and the household environment. Parental education was collected based on parent's self-reports of number of school grades completed. The median for both mothers and fathers was 2 years. Parental aspirations for children were also obtained in separate interviews with fathers and mothers. They were asked a series of questions pertaining to aspirations for their children's schooling and future occupation. A composite score was constructed using the responses to the individual items.

Table 17.6 presents the bivariate relationships of the cognitive scores to parental traits. Parents with higher cognitive scores tended to have sons and daughters with higher cognitive scores. Parents with more years of schooling tended to have girls with higher cognitive scores, but there was no such relationship for boys. Parents with higher aspirations for their children tended to have sons with higher cognitive scores, but not daughters.

Table 17.6 also shows the partial correlations of parental characteristics and cognitive scores using dietary quality as a co variate. When the covariance with dietary quality is removed, only the correlations between the cognitive scores of mothers with their daughters' and cognitive scores of fathers with their sons' remains significant.

Turning to the behavioral variables (Tables 17.7 and 17.8), boys who were from wealthier households and whose fathers performed better in the cognitive testing were seen as more *socially competent* and *less withdrawn* and *introverted* by their teachers. Higher paternal education and aspirations were associated with more *acting-out* behaviors and less *introversion*. The significant associations became weaker when dietary quality was entered as a covariate.

Table 17.5: Nutritional and economic characteristics by school grade.

	Grade 1	Grade 2	Grade 3[a]
Performance	25.2[a]	32.4[b]	39.0[c]
Verbal	22.7[a]	28.9[b]	35.4[c]
% Animal kcal	5.3[a]	5.6[a]	9.0[b]
Wt/age (Z score)	-1.6[a]	-1.2[b]	-1.1[b]
Ht/age (Z score)	-2.0[a]	-1.4[b]	-1.3[b]
SES	156.6[a]	199.8[a,b]	241.5[b]

[a] Children who were in grade 3 or 4 were combined.
Different letters indicate significant differences at $p < 0.05$.

Table 17.6: Relationships of cognitive scores to social characteristics: bivariate and partial (dietary quality controlled) correlations.

	BOYS (N=53)				GIRLS (N=54)			
	Performance		Verbal		Performance		Verbal	
	Bi	Part	Bi	Part	Bi	Part	Bi	Part
SES	0.20	-0.08	0.35*	0.20	0.43†	0.25	0.58†	0.46†
Grade	0.51†	0.38†	0.68†	0.63†	0.51†	0.41†	0.72†	0.67†
Mother's Cog Perf	0.28*	0.19	0.24‡	0.14	0.54†	0.37*	0.43†	0.44†
Father's Cog Perf	0.50†	0.41*	0.42†	0.31‡	0.45†	0.17	0.31*	0.24
Mother's Education	0.21	0.08	0.18	0.05	0.30*	0.12	0.28*	0.21
Father's Education	0.06	0.07	0.25‡	0.06	0.36*	0.02	0.27‡	0.14
Mother's Aspirations	0.29†	0.16	0.15	0.11	-0.08	-0.10	0.05	0.02
Father's Aspirations	0.24‡	-0.03	0.41†	0.23	-0.09	-0.21	-0.05	-0.18

* $p < 0.05$, † $p < 0.01$, ‡ $p < 0.10$

Table 17.7: Relationships of acting-out and withdrawn scores to social characteristics: bivariate and partial (dietary quality controlled) correlations

	BOYS (N=42)				GIRLS (N=41)			
	Acting-Out		Withdrawn		Acting-Out		Withdrawn	
	Bi.	Part	Bi	Part	Bi	Part	Bi	Part
SES	0.10	0.09	-0.31†	-0.29	0.06	-0.03	-0.14	-0.11
Grade	0.06	0.05	0.15	0.27	-0.08	-0.16	0.07	0.11
Mother's Cog Perf	-0.09	-0.11	0.18	0.25	0.11	0.01	0.00	0.03
Father's Cog Perf	0.25	0.32•	-0.41†	-0.33•	-0.13	-0.19	-0.12	-0.01
Mother's Education	0.15	0.15	-0.01	0.03	0.15	0.12	-0.12	-0.01
Father's Education	0.36†	0.33	-0.13	0.13	-0.17	-0.25	-0.04	0.03
Mother's Aspirations	-0.18	-0.17	0.11	0.18	0.21	0.20	0.19	0.20
Father's Aspirations	0.41‡	0.45‡	-0.09	-0.01	0.23	0.21	0.18	0.17

• $p < 0.05$, † $p < 0.01$, ‡ $p < 0.10$

Table 17.8: Relationships of social competence and introverted scores to social characteristics: bivariate and partial (dietary quality controlled) correlations.

	BOYS (N=42)				GIRLS (N=41)			
	Social Competence		Introverted		Social Competence		Introverted	
	Bi.	Part	Bi	Part	Bi	Part	Bi	Part
SES	0.40†	0.29	-0.35†	-0.29	0.25	0.01	-0.39†	-0.36†
Grade	0.18	0.06	-0.29•	-0.11	0.35†	0.25†	0.02	0.07
Mother's Cog Perf	0.12	-0.03	-0.08	0.05	0.18	0.08	-0.34†	-0.32•
Father's Cog Perf	0.38†	0.07	-0.50‡	-0.41†	0.15	-0.07	-0.14	-0.04
Mother's Education	0.10	0.16	-0.04	0.10	0.15	0.00	-0.20	-0.18
Father's Education	-0.06	0.09	-0.33•	-0.31	0.16	-0.12	-0.10	0.04
Mother's Aspirations	0.27	0.24	-0.28	-0.18	-0.21	-0.31•	0.13	0.14
Father's Aspirations	0.00	0.19	-0.43†	-0.37	-0.08	-0.13	0.08	0.09

• $p < 0.05$, † $p < 0.01$, ‡ $p < 0.10$

Girls from wealthier households and whose mothers performed better in the cognitive testing were rated less *introverted*. Controlling for dietary quality reduced the magnitude of the associations as seen in the boys.

Multivariate Models

Multiple regression models were used to assess of the relationships of cognitive performance and behavior ratings to nutritional status and the social variables. The 'best' regression models were identified using step-wise regression (PROC STEPWISE).

Table 17.10 presents the results for cognitive performance variables. For boys, dietary quality and school grade were the best predictors of *performance scale*, and school grade was the only significant predictor of *verbal scale*. For girls, the father's cognitive score and school grade were the best predictors of *performance scale*, while SES and school grade were the best predictors of *verbal scale*.

In the behavioral ratings analyses, principal components analysis was used to reduce six parental variables to three (i.e. mother's cognitive performance and education, father's cognitive performance and education, and parental aspiration for their children's schooling and occupation. The regression models for *acting-out* (boys) and *withdrawn* and *introverted* (girls) failed to have significant predictors.

For boys, the parental variables were the best predictors of *withdrawn* and *introverted* behaviors. *fatness* was the most significant predictor of *withdrawn*. *Socially competent* was best predicted by *dietary quality* for both boys and girls. Among girls, *Acting-out* was predicted best by a variety of factors including nutritional status, school grade, and mother's cognition and education.

Differential Responsiveness Between the High and Low Dietary Quality Groups

A set of analyses was focused on the nested effects of environmental factors within dietary quality, after controlling for the main effect of dietary quality. For these analyses, subjects were divided into high and low groups based on the median value of the dietary quality variable, independent of sex. No differences were seen in the relationships of anthropometry and social variables to either cognitive performance or verbal scores by category of dietary quality. However, boys' associations between behavioral characteristics and environmental factors (i.e. SES, mother's and father's cognitive scores and aspiration) were significant only among those from the high dietary quality group. For girls, some environmental factors (i.e. SES, mother's cognitive performance and education) tended to be more strongly related to the behavioral characteristics in the low dietary quality group as compared to the high group, yet these differences did not reach a statistically significant level ($p<0.05$). In the high dietary quality

Table 17.9: 'Best' regression models for behavioral scores.

	Behavioral Variable	Model R-Square	Predictive Variable	Parameter Estimate	t-statistic	Type III SS p value
Boys	Acting-out	.20†	Size	-.365	-2.26	.0307
(n=33)			Father's cog.	.057	2.57	.0153
	Withdrawn	.32†	Grade (res.)	1.648	2.80	.0091
			Father's cog.	-.235	-3.06	.0047
	Soc. Comp.	.23†	Fatness	.235	2.36	.0247
			SES (res.)	.003	2.22	.0336
	Introverted	.21†	Size	-.194	-1.91	.0646
			Fatness	-.207	-2.07	.0455
Girls	Soc. Comp.	.15†	Diet. qual.	.197	2.54	.0154
(n=37)	Introverted	.10*	Size	-.177	-1.95	.0596

* $p<0.10$, † $p<0.05$, ‡ $p<0.01$

Table 17.10: Regression models for cognitive scores: using raw values.

	Cognitive Variable	R-Square	Predictive Variable	Parameter Estimate	t statistic	Type III SS p value
Boys	Perform.	.34†	Diet. qual.	4.219	2.57	.0134
(N=51)			Grade	4.179	2.91	.0054
	Verbal	.47†	Grade	6.345	6.71	.0001
Girls	Perform.	.39†	Father cog.	0.444	2.34	.0244
(N=43)			Grade	5.401	3.55	.0010
(N=53)	Verbal	.62†	SES	0.034	3.70	.0005
			Grade	6.557	6.24	.0001

* $p < 0.05$, † $p < 0.01$

group, *acting-out* and *withdrawn* were associated with father's education and aspiration at $p<0.10$, respectively.

Discussion

These results suggest that food intake, specifically dietary quality, is related to important cognitive, behavioral, and educational characteristics of school-aged children. In the bivariate analyses, better dietary quality was significantly associated with higher scores on both the Performance and Verbal Scales. Boys who had a better quality diet and showed better growth were rated by their teachers as significantly more *socially competent* and less *introverted*. For girls, dietary quality, but not the anthropometric measures, was significantly associated with the *acting-out* and *socially competent* behavioral scales.

Of the anthropometric measures, *size* was a consistently better predictor of cognitive performance than *fatness*. This may indicate that the functional significance of growth measures is related to the duration or timing of nutritional deficits. In Chapter Thirteen the better growth and larger size of the preschoolers was shown to be associated with better dietary quality, and children were shown to *track* (retain their relative size ranking over time). Therefore, the cognitive performance and behavior of school-aged children probably reflects the effects of early stunting on early learning patterns, and these effects have persisted into the school-age period. When we compare dietary patterns of preschoolers in the community to those of the school-age children, we find no major differences. Thus, it is likely that the school-age children who were consuming poor diets during this study were also consuming poor diets earlier in their lives when their growth rates were higher, and the impact on anthropometry was greater. The current pattern of food intake may also reflect the child's long-standing history of nutrient consumption.

The association between cognitive performance and school grade is an important and predictable finding because children's literacy and exposure to problem solving increases with experience. However, attained school grade was not a simple function of chronological age among the children. The mean age of the first and second graders was not significantly different, nor was the mean different between children in grade 2 and those in grade 3 and higher. Among children of the same age, those from economically better-off families tended to be in a higher school grade, indicating that they probably had been sent to school at a younger age. They were also larger in size and fed better quality diets. Parental perceptions that a child is ready for school may be influenced by the child's size. Also, the association of size with behavioral variables suggests that some children are not emotionally and behaviorally ready for school. It is also likely that economic constraints lead to delays in school entrance for children who are nutritionally disadvantaged. The relative influence of parental perceptions versus economic considerations cannot be ascertained from these data. However, the value of more schooling for improving cognitive performance among children from a nutritionally at-risk population is clearly established.

Considering the importance of teachers' influence on children's educational achievement in school settings, the teachers' perception of the children's behavior has significant implications. The finding that a child's poor nutritional status is a risk factor for negative perception by his or her teacher implies that malnourished children have important social and biological disadvantages.

The results also show clear sex differences in the pattern of relationships among nutritional variables, socio-economic status and cognitive performance. For boys, the significant bivariate associations of dietary quality and anthropometry with cognitive performance remained significant in simple partial correlations controlling for SES. For girls, however, when SES was controlled, diet and anthropometry were not significantly correlated with performance. For the behavioral measures, current economic and social characteristics were associated for the boys, whereas, few significant associations were found for girls. For boys, these associations were more distinct among those who had relatively higher dietary quality as compared to those with a lower quality diet. The behavioral variables also show sex differences in the types of behaviors predicted best by nutritional and social variables used in this study: *withdrawn* and *introverted* for boys and *acting-out* for girls.

These sex differences may be due in part to the influence of sex-role stereotypes in many social environments. In most rural villages, sex-appropriate behavior is well defined. This stereotyping appeared to influence teachers' perceptions of typical or preferred behaviors for boys and girls. In the Mexican rural context, reticence may be more acceptable for girls than for boys, so that boys who display withdrawn behavior are more likely to be noticed and negatively evaluated, whereas, girls with the same behavior traits would not be described as such. On the other hand, the tolerance for active, aggressive behaviors in girls may be low, leading to the results observed.

Our results suggest that the immediate social context of the household may exert a greater, or more limiting, influence on the development of girls than it does on boys. In this cultural setting, as in many others, girls are expected to remain close to home, and they experience considerably greater restrictions on their freedom of movement. All of the households in Solís are poor judged by the standards of industrialized countries, but some are poorer than others. It is likely that children in low SES households receive less stimulation, less exposure to new ideas and have fewer opportunities for intellectual challenges. For girls who spend a larger percent of their time within the confines of the household, these conditions may be of over-riding significance for their development. Boys, however, may be venturing further from home, and encountering a variety of environments. For them, better nutrition may be associated with greater activity, which leads to opportunities for a wider range of experience and challenge.

In this research, as in all non-intervention studies of nutrition and cognition performance, a central problem for the interpretation of the results is the issue of causality versus association. It is important to recognize the effect of the statistical procedures that are selected to address the issue of confounding variables. Commonly investigators employ analytic techniques in which shared variance between nutrition and SES is assigned to the social environment for which SES serves as a marker. This practice may lead to over-control in the statistical analyses as better diet quality is a consequence of higher SES. As a result, the importance of poor nutrition in contributing to developmental disadvantage may be masked if SES is included in the model. On the other hand, it is plausible that the strength of the dietary quality variable is due to its being a sensitive marker, or "proxy", for other non-dietary social variables that actually influence cognitive performance. We cannot rule out this conclusion. However, the analyses presented suggest that nutrition does play a significant role in affecting the cognitive performance, behavior, and education of the children in this study, and it is likely that similar relationships exist in other populations with wide-spread mild-to-moderate malnutrition.

Policy Implications

- Marginal malnutrition is associated with poorer cognitive, behavioral and educational performance of school-aged children. As for preschoolers (Chapter Fifteen), dietary quality is the important issue, not energy or protein intake.

- The children's size (weight, height and head circumference) was a strong predictor of performance while current fatness was not, showing that growth stunting (due to a poor quality diet) in the first year or two of life (Chapter Five) has adverse consequences for later cognitive and behavioral development. This further supports the need for interventions to prevent early growth-faltering.

- Nevertheless, current dietary quality also predicted development, and it is quite possible (especially given the prevalent micronutrient deficiencies in these children described in Chapter Eight) that improving the micronutrient status of school-aged children can still be of benefit.

- Boys who consume poor quality diets more likely to be evaluated as withdrawn, whereas girls are not. This probably reflects sex-role stereotypes on the part of evaluators (the teachers) concerning appropriate behaviors. When culturally appropriate, educators should be made aware that a withdrawn child may signal marginal malnutrition.

- More schooling may improve cognitive performance of marginally malnourished children. Any constraints to school attendance should be minimized.

- The cognitive and behavioral development of girls are more negatively affected by poor socioeconomic conditions than is the case for boys, who are probably less restricted to the home. This indicates that an unstimulating environment adversely affects development, in addition to the influence of poor dietary quality. Again, this raises the importance of a stimulating environment at school for improving the development of these marginally malnourished children.

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Chapter Eighteen: Conclusions

The presence of marginal malnutrition in the Solís Valley is not immediately apparent. The weight-for-height of children is normal, severe malnutrition is rare and occurs only secondarily to disease, and there is little evidence that families are "hungry". On the other hand, children are growth-stunted, and diets are monotonous. The situation in Solís is similar to that in many rural (and urban) populations in poor countries. Thus, the strong evidence for chronic, almost universal malnutrition in the Solís population, and for subsequent deficits in functional performance, should alert nutrition and health professionals and policy-makers to the probability that the Nutrition CRSP results may be applicable to many of the world's less advantaged populations. The generalizability of the results is also supported by the striking similarity of the major research findings across the Mexico, Egypt and Kenya projects.

One important observation in the Mexico Nutrition CRSP is that growth-stunting (in both weight and height) occurs primarily during the first two years of life. It is most rapid starting around 3 months when the nutritional status of the infant is dependent primarily on nutrients stored during fetal development and consumed from breast milk during lactation. This early growth failure is typical of populations in developing countries. Early growth-failure means that, at least without interventions, an individual is likely to be small for the rest of their life; this may be true even from the time of fetal development because size at birth was a strong predictor of size at 8 months and children "track" in their growth channels from an early age. Also, the mother's body mass at conception predicts the weight and length of her infant, from birth to at least 8 months. This points to inter-generational effects of growth-stunting, which can only be improved by improving the nutritional status of the mother and/or of the child in early infancy. The notion that the growth-failure can be ascribed to "genetic" differences is discountable based on the fact that Mexican-American children who move to the U.S. at an early age do grow to a similar size as the U.S. children on whom the reference is based.

The importance of the early growth-stunting is that it is accompanied by marked deficits in functional performance. For example, even by 6 months of age, smaller infants have deficits in mental and motor performance, are less happy, less interactive and more withdrawn. Smaller preschoolers and schoolers perform less well on cognitive tests, and are also less interactive and more withdrawn. Smaller schoolers are rated more poorly by their teachers. Smaller women give birth to smaller infants, who grow more slowly, and in turn are more stunted.

What role does nutrition play in this growth-failure? The Nutrition CRSP was designed to test whether *energy* deficit, resulting from lack of food, affected human functions. The CRSP was conceived at a time when it was becoming clear that, contrary to scientific opinion in earlier years, protein was unlikely to be the nutrient limiting the growth and function of most populations. Energy deficit seemed to be the most likely culprit.

One of the most important and surprising findings of the Mexico Nutrition CRSP is that neither energy nor protein deficiency is the primary nutritional problem. This is supported by several lines of evidence. There is virtually no association between the usual energy or protein intake of children and any functional outcomes including growth. The average energy intake of the population groups studied almost exactly matches calculated requirements, and protein intakes are considerably above requirements. Even essential amino acid intakes are adequate, at least for healthy children. Although weight gain in pregnancy is low this cannot be ascribed to lack of food availability; as soon as the women start breastfeeding their energy and protein intakes increase dramatically. The women are relatively fat. Finally, factors that might be expected to result in a low energy intake, such as a large number of persons to feed in a household or low socioeconomic status, do not affect the amount of energy that individuals or households consume. Rather, they influence the types of food consumed and adversely affect dietary quality.

Poor dietary quality is the main nutritional problem. The term "poor quality" describes a diet low in vitamins and absorbable minerals (micronutrients). Individuals can be classified in terms of where they rank on the continuum between a poor quality diet, in which most energy comes from *tortillas*, beans and pasta, and a better (although rarely good) quality diet that contains more animal products, fruits and vegetables. Those children who consume better quality diets grow faster in length and weight, perform better on cognitive tests and in school, and behave in a more interactive, less apathetic manner. Even at birth, infants perform better on neurobehavioral exams if their mother had a higher quality diet during pregnancy, and better iron and vitamin B_{12} status. Infant cognitive performance and behavior at 6 months was also related to mother's dietary quality and nutritional status.

With respect to vitamin intakes, dietary information shows the children's diets to provide only one third of the recommended amounts of ascorbic acid, vitamin A and vitamin E. There is also a high probability that the children's intakes of riboflavin, niacin, pantothenic acid, and vitamins B_6 and B_{12} are inadequate to meet requirements. Adults have very low intakes of vitamin B_{12}, vitamin A and vitamin E, and for women ascorbic acid consumption is far below requirements.

The high phytate and fiber content of the maize-based diets undoubtedly cause mineral deficiencies in all age groups. Anemia was found in half of the men and women and two-thirds of the children. Iron deficiency is a major problem for children, especially preschoolers, and for women. The pregnant mother's intake of absorbable iron, and her iron status, predict the neurobehavioral development of her infant at birth and cognitive development and behavior at 6 months. Vitamin B_{12} deficiency, formerly thought to occur rarely in developing countries but analyzed here using a more accurate method than in previous international surveys, occurred in a substantial number of individuals from all age groups. Most lactating women had deficient levels of this vitamin in their breast milk. Individuals were at most risk of iron and vitamin B_{12} deficiency if the quality of their diet was poor. The possibility exists, but was not determined in the CRSP, that subclinical infections and endemic parasites such as *Giardia lamblia* further exacerbate micronutrient deficiencies.

Because the CRSP was designed to investigate energy deficiency, biochemical analyses were limited to indicators of iron and vitamin B_{12} status. Subsequent biochemical studies in preschoolers in this community show that vitamin A and E deficiencies are also highly prevalent. The high probability of zinc deficiency is also being investigated. Consequently, intervention strategies for improving the micronutrient status of this population must take into consideration the fact that there are multiple deficiencies, and it is impossible to say which are the most important.

A high prevalence of micronutrient deficiencies is likely to be found in many of the world's poorer populations who subsist on staple foods high in phytate and fiber and low in vitamins and absorbable minerals. The Egypt and Kenya Nutrition CRSP projects find similar results, although in Kenya energy deficiency certainly existed especially during periods of food shortage. It is also obvious, but not often considered, that populations who suffer from an inadequate quantity of food undoubtedly suffer from poor dietary quality and subsequent micronutrient deficiencies as well. We do not wish to suggest that it is easy for the residents of Solís, or of other poor communities, to obtain enough of their staple food such as *tortillas*. In fact, they devote a major portion of their resources to the procurement of maize and have to resort to employment far out of the community in order to buy enough food. In a bad harvest year, which happens frequently, the situation is likely to be worse with more households suffering from an inadequate quantity as well as quality of food. The main point, however, is that resources of most families are insufficient to buy enough quality foods such as milk and other animal products.

The results presented in this report point to two indisputable conclusions that have obvious policy implications. First, there is a need to test interventions that will improve the micronutrient status of marginally malnourished populations. Secondly, pregnant and lactating women, infants and perhaps preschoolers are the most urgent candidates for these interventions. The evidence suggests that supplying micronutrients to pregnant women will improve infant outcomes at birth and at 6 months, and perhaps for much longer than this. Improving the micronutrient status of lactating women should increase the concentration of vitamins in breast milk, as well as protect the mother against depleted micronutrient stores when she enters the next pregnancy. In addition the ubiquitous growth-stunting might be prevented if the micronutrient intakes of infants and preschoolers are improved. Without these kinds of interventions the promotion of exclusive breast-feeding during this period of growth-failure is unlikely to lead to the results which this policy is intended to produce. Finally, micronutrient interventions may improve the growth of schoolers as well as their cognitive, behavioral and school performance.

Considerable work is needed to decide which interventions are most appropriate and effective. Given the evidence for multiple deficiencies a "magic bullet" approach, in which one or a few selected micronutrients are given as a supplement, is unreasonable. In fact, single supplements such as iron might well impair the absorption of other micronutrients, such as zinc, still further.

From a public health perspective it might be possible to convince pregnant and lactating women to take multivitamin-mineral supplements regularly, and to give them to their children. Unfortunately, most micronutrient supplements would have be taken almost daily, unlike the situation for vitamin A where a single dose will increase stores for many months.

Other possible intervention strategies include special food subsidy or distribution programs aimed at women and children, such as the Women, Infants and Children special supplemental food program in the US. Weaning foods lower in phytate and higher in micronutrients, or enriched products such as *atole* or fortified milk substitutes, might be used by the mothers. The amount of milk fed to preschoolers seems to be an important predictor of their growth and function, but currently milk use is constrained by its price, availability, and lack of refrigeration in community stores and homes. These are all constraints that could be reduced by appropriate government policy. Another possible option is fortification of maize, when it is ground at the community mills. Education concerning the need to include some source of ascorbic acid (such as limeade) with meals might be effective; this might improve the iron status of women and children dramatically. Agricultural programs should ensure that households have access to animal products, especially for women and children. For many populations, policies to help them produce "more of the same" staple food will not improve nutritional status if it is low in absorbable micronutrients, unless it can be sold for cash to buy foods of better quality.

The next step must be to devise and test locally-appropriate methods for improving micronutrient status, and to evaluate their effect on outcomes such as growth and other sensitive functional indicators of marginal malnutrition revealed by the Nutrition CRSP. In fact, one of the main contributions of the CRSP has been to test many of the more complex and time-consuming indicators of malnutrition; the results described above can now be used to design more practical simplified versions useful for future evaluations.

The "bad news" from this report is that marginal malnutrition may be even more prevalent than formerly recognized. It is also clear, once and for all, that it has adverse effects on human development and function that simply cannot be tolerated. The "good news" is that fewer people may be suffering from food, and subsequently energy and protein, shortage than previously assumed. Perhaps we should have realized this before. Populations who are chronically and marginally deficient in energy will continue to lose weight and die in the long-run, unless this deficit is offset by physiological and/or work-related "adaptations" in energy expenditure. Even where there is seasonal weight loss due to marginal energy deficit, evidence for such adaptations is meager. This is not to suggest that all populations have enough food and energy; where there are periods of food shortage, energy deficiency will certainly occur.

Currently there is a state of apathy in international organizations and foundations concerning the feasibility of nutrition intervention efforts. Perhaps this emanates in part from the assumption that sweeping socioeconomic reforms are a prerequisite to dealing with the ubiquitous presence of growth-failure caused by marginal malnutrition. A further disincentive has been the lack of a scientific strategy for identifying the most effective food and/or nutrient interventions to ameliorate the problem. The results of the Nutrition CRSP now provide a scientific basis for effective, focussed solutions at the regional, national and international level. The issue in many populations is how to provide better quality food, and/or micronutrients, especially in pregnancy and the early postpartum period. There are many potential solutions which should be implemented and evaluated.

We urge that agencies responsible for assessing and improving the food supply and nutritional health of human populations use the findings of the Nutrition CRSP to enter into a new collaborative effort to reduce the prevalence of marginal malnutrition and its damaging effects on the quality of human life.

Appendix.
Publications from the Mexico Nutrition CRSP

Technical Reports

Mexico Project Final Report (Allen LH, Pelto GH, Chavez A), submitted to the University of California, Berkeley, November, 1987.

Pelto GH, Martinez H, Allen LH, Chavez A. "Adult Morbidity in the Solis Valley, Mexico." Submitted to World Bank, 1990.

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Refereed Publications

Goodman AH, Allen LH, Hernandez GP, Amador A, Arriola LV, Chavez A, Pelto GH. "The Prevalence and Age at Development of Enamel Hypoplasias in Mexican Children." *Am J Phys Anth* 72: 7-19, 1987.

Bravo-Ureta B, Ely RD, Pelto PJ, Meneses L, Allen LH, Pelto GH, Chavez A. "Determinants of Rural to Urban Labor Movements in Mexico: A Household Perspective." *Proceedings XX International Conference of Agricultural Economists*, 1988.

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Refereed Publications (in press or submitted)

Pelto, GH, Urgello J, Allen LH, Chavez A, Martinez H, Meneses LM, Capacchione C. "Household Size, Food Intake and Anthropometric Status of School-Age Children in a Highland Mexican Area." *Soc Sci Med* 33: 1135-1140, 1991.

Zorn MW, Stanek EJ, Chavez A, Allen LH, Pelto GH, Backstrand JR. "The Magnitude of Memory Loss in Recall Morbidity Data." Submitted to *Stat Med.*

Pelto GH, Lung'aho MS, Allen LH. "Nutrition and reproduction: some cross-cultural issues." *Smithsonian Institute Press*. In Press.

Black AK, Allen LH, Pelto GH, de Mata M, Chavez A. "Dietary and Other Factors Associated with Risk of Iron and B_{12} Deficiency in Men and During Reproductive Stages of Women in Mexico." Submitted to *J Nutr.*

Oh SY, Pelto GH, Allen LH, Goldman J, Martinez E, Chavez A, Findley G. "Diet, Growth and Cognitive Performance in School-Age Mexican Children." Submitted to *Pediatrics*.

Allen, LH. "Nutrition and Function: A Comparison of INCAP and CRSP Conclusions." Submitted for *J Nutr* supplement.

Martinez H, Allen LH, Chavez A, Pelto GH, Rios E, Backstrand JR, Black AK and Ely RD. "Factores en la Dieta que Afecton el Crecimiento de Niños en el Medio Rural. Submitted to *Arch Latinoamer Nutr.*

Refereed Publications (in preparation)

Allen LH, Stanek EJ, Chavez A, Pelto GH. "An Autoregression Model of Mexican Preschooler Growth in Relationship to Diet, Morbidity, and Household Variables." In preparation for *Am J Clin Nutr.*

Backstrand JR, Allen LH, Pelto GH, Chavez A, Molina E. "Re-thinking Food Consumption: An Alternative Approach for Describing Food Consumption." In preparation for *J Am Diet Assoc.*

Backstrand JR, Pelto GH, Allen LH, Pelto PJ, Chavez A, Meneses LM, Molina E. "Poverty, Household Energy Needs, and Diet Quality in Rural Households of the Mexican Central Highlands." In preparation for *Human Organization.*

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Pelto GH, Backstrand JR, Allen LH, Chavez A, Meneses LM, Pelto PJ. "The Relationships of Economic Status to Food Intake and Size in Three Periods of Childhood Among Children in the Mexico CRSP Project." In preparation for *Ecol Food Nutr.*

Pelto GH, Backstrand JR, Allen LH, Chavez A, Meneses LM, Molina E. "Social Characteristics Related to Intra-Household Variation in Dietary Intake in the Mexico CRSP Project." In preparation for *Nutr Res.*

Pelto GH, Martinez H, Capacchione C, Allen LH, Chavez A. "Breastfeeding, Birth Intervals and Infant Feeding Practices in a Rural Area of Highland Mexico: Results from the Mexico CRSP." In preparation.

Scanlon KS, Allen LH, Tellez E, Pelto GH, Chavez A. "'Small is Unhappy': Effects of Marginal Malnutrition on Activity and Behavior of Mexican Preschoolers." In preparation for *Am J Clin Nutr.*

Abstracts

Allen LH, Scanlon KS, Pelto GH, Chavez A. "Maternal Time Allocation and Nutritional Status in Mexico: Relationships to Child Health." Abstracts of the American Anthropological Association, Chicago, November, 1987.

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